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ABSTRACT

The major objective of this study was to demonstrate that an effective first-year apprentice training program (in the metal trades) could be developed in which performance was the primary criterion of success. The Performance Based Apprentice Training (PBAT) experimental group completed a full year of related instruction in an average of 61 hours (compared to an average of 187 hours for the comparison group), and scored 30 percent higher on a related instruction final examination. After less than 40 hours of training, the ratings of quality of shop performance of the PBAT group exceeded those of the comparison group after nearly 1,200 hours of shop training. The introduction of a systematically organized and administered self-paced program utilizing criterion referenced performance standards is likely to result in a significant reduction in training time, since it has been demonstrated that the most critical variable responsible for producing competent skilled tradesmen is not the number of hours spent in training, but the quality, intensity, effectiveness, and sequencing of training experiences. (Included are a 38-item bibliography and appendixes relating to descriptions of outstanding programs, behavioral objectives for related and shop instruction, review exercises, and forms and questionnaires utilized in the study.) (SC)

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IMPROVING PERFORMANCE IN TECHNICAL AND APPRENTICE TRAINING

A Pilot Study of PBAT (PERFORMANCE BASED APPRENTICE TRAINING)

by

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The study reported here provided the author with a welcome and unique opportunity to test -- under the harsh realities of the industrial environment -- the concepts and methods of a new apprentice training system (PBAT -- Performance Based Apprentice Training) that he and his staff had developed as a result of pilot studies conducted in a major manufacturing company during 1966-67.

Special thanks are due to Dr. Richard McKillip of the U.S. Civil Service Commission for his initial interest in our work and for arranging for us to use an experimental version of a selection test developed by the U.S. Civil Service Commission. To Dr. Howard Rosen and William Paschell of the Office of Research and Development, Manpower Administration, U.S. Department of Labor, we owe unmeasured gratitude. Without their continued interest, support and guidance, the study would have been impossible.

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A.E. Oriel
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SUMMARY OF FINDINGS

The following pages summarize briefly the major findings, implications and recommendations that emerged from the study. Such summaries, because of their necessary brevity, often fail to explain fully the reasons behind a specific result or recommendation. For complete understanding of the results summarized here, the reader is urged to read the full report.

1. Using the Performance Based Apprentice Training system developed for this study, the experimental (PBAT) group of first year metal trades apprentices completed a full year of related instruction in an average of 61 hours compared to the 144 hours usually recommended for the first year of apprenticeship.
2. In relation to a comparison group that had received an average of 187 hours of conventional related training, the PBAT group (with 61 hours) scored 30 percent higher on a related instruction final examination.
3. On a follow-up test 3 to 9 months later, the PBAT group again scored significantly higher than the comparison group. During this period their performance level had declined only 10 percent from the level attained immediately following training.
4. After less than 40 hours of training the ratings of the

quality of the shop performance of the PBAT group (on the four basic machine tools: mills, lathes, drills, surface grinders) exceeded those of the comparison group after nearly 1,200 hours of shop training.

5. The data demonstrate that the time required for first year apprentices to learn to perform to an acceptable criterion in both related and shop training varies widely from one individual to the next. They also suggest that if time is allowed to vary, the average apprentice will complete training in considerably less time than the standard hours now recommended. (2,000 hours total time; 144 hours of related instruction)
6. A number of studies have revealed with great consistency that one of the more serious shortcomings of current apprentice programs is the lack of uniform and detailed shop performance criteria either to define in measurable terms the qualifications of a journeyman or to determine movement of apprentices through training.
7. A second is the traditional emphasis on number of hours on course, rather than performance, as the primary criterion of success.
8. The data on the performance of the PBAT subjects and their attitudes toward the experimental program -- especially its self-pacing aspect -- strongly suggest that one effective future direction for apprentice training is not to attempt to set new, diminished time

standards, but to establish objectively determined and measurable performance standards and to allow training time to vary.

9. It is possible, with a systematically organized and administered self-paced program, to achieve a uniformly high level of achievement by setting absolute (criterion referenced) performance standards. And it is likely that such a program will result in a significant reduction in training time.

10. Individual differences in learning ability can be utilized more fully than they have been to produce competent performance in both related instruction, and shop training.

11. Modular training can be used effectively to bring about better temporal contiguity between related instruction and shop training.

12. Advanced placement in an apprentice training program can be done accurately and fairly through the use of standardized performance and achievement tests.

13. Instructor time in both related and shop training can be reduced substantially through the use of a self-paced training program such as PBAT.

14. Compared to most conventional apprentice programs, such an intensive training program at the beginning of the first year, produces apprentices who are able to perform a wider variety of shop tasks -- with greater confidence --

much earlier in their first year.

15. Reading and arithmetic achievement were, in this study positively and significantly related to performance in related instruction but not to shop performance.

16. The data suggest, however, that with trainees whose reading skills are below eighth grade, the quality of administration of the PBAT program is as important to success as is reading and arithmetic skill level. This relationship appears to break down with reading levels below grade 6.5.

17. Trainees and administrators had generally positive attitudes toward the experimental PBAT program.

18. If employers, unions and government are genuinely interested in improving apprentice training, it is recommended that manpower policy seriously consider establishing apprentice and journeyman performance standards under which measured performance is the primary criterion of both movement through apprentice training and of attainment of journeyman status. Precedents already exist for such a program in the Ford Motor Company -- UAW program and in the new Canadian program. (See Appendix A)

19. The U.S. Department of Labor could make a major contribution to the development of more effective apprentice training. A cooperative effort by the Office of Research and Development and the Bureau of Apprentice and Training to establish performance oriented apprentice policies and

to help industry implement them could have highly beneficial long-range results. Such policies should be firmly grounded in an empirical approach to the development of measurable and uniform performance standards.

20. Such a program would also provide the objective measures needed to help companies now struggling with the problem of how to evaluate apprentice and journeyman performance with the objectivity and relevance required by the EEOC. The U.S. government could aid materially in this effort by a long-range, systematic program to develop and disseminate information to industry on the use of a behaviorally oriented performance development system.

21. Research exploration of the relative roles of selection versus training and administration in producing competent journeymen could also be of material benefit to industry, unions, apprentices and the skilled community at large.

22. Other steps that could be taken by government to ensure maximally effective apprentice training are:

    (a) Encourage and support the development of behaviorally oriented selection and training materials -- both printed and audio/visual -- that have reading skill level that are appropriate for the jobs involved and the trainees who are likely to use them.

    (b) Publish and disseminate information on new training technology to industry and government apprentice coordinators on a regular basis.

(c) Hold regular regional conferences of both industrial and government personnel who are responsible for apprentice training to encourage both continuous evaluation of apprentice training programs and a continuing search for innovation in training methods. The apprentice training system in the U.S., because it represents the epitome of skill training, should be the leader -- not the follower -- in the search for more innovative, effective training methodology.

23. Finally, perhaps the most effective way to accomplish all of the recommendations made in this report, would be for the U.S. government to establish an on-going research and development program in these areas -- perhaps housed in regional demonstration centers. Such centers could simultaneously perform important training functions and conduct empirical research on the problems of apprenticeship training uncovered by all of the recent studies.

INTRODUCTION

Historical records indicate that the indentured apprenticeship has, for more than 4,000 years, been the single most important, most prevalent and perhaps most effective method of training skilled craftsmen. Its development traces a continuous thread from earliest recorded history through Greek, Egyptian, Roman and European societies to our highly industrialized present-day America. It reached its peak during the era of the private guilds in medieval Europe and appeared in America with the earliest settlers.

Until the beginning of the twentieth century apprentice training in America followed the classical European traditions. Young boys were apprenticed to master craftsmen from whom they learned everything they needed to know and be able to do in order to attain journeyman status. This system changed little until the turn of the century when the growth of modern industry, the demands of a rapidly developing technology, and the scarcity of skilled immigrant craftsmen forced American industry into a more systematic and intensive training effort. This period marked the dawn of modern apprentice training, as we know it today, consisting of both shop or job training and related schooling covering what is usually referred to as the "theory" which underlies

trade practices.

Many changes have occurred during the past 50 years in the methods of administering apprentice training, most notably as a result of the creation in 1934 of the Federal Committee on Apprenticeship Training and the passage in 1937 of the Fitzgerald Act. This act charged the U.S. Secretary of Labor with the task of promoting the development of apprenticeship programs and quality standards. It also led to the creation of the Bureau of Apprenticeship and Training, many state apprentice bureaus and a large number of local industry/labor joint apprenticeship committees.(20)

Despite the many administrative changes which grew out of the 1937 National Apprenticeship Act, the philosophy underlying training and the methods used to train apprentices appear to have changed little during the past 40 to 50 years. In the typical apprentice training program today -- as it has been for many years -- apprentices are selected based on a set of criteria which include -- among other things -- number of years of education (usually 10th or 12th grade), evaluation of school records, scores on a battery of selection tests and the results of personal interviews.

Once accepted on a program, the apprentice is indentured for the duration of his apprenticeship -- most commonly 4,000 to 8,000 hours, (or two to four years) depending on the trade involved. He or she is usually required to take a total

of 576 hours of related instruction (144 hours per year). In industry the apprentice usually receives shop instruction by working with a journeyman or an advanced apprentice on regular work assignments that come through the shop. In most of the more formalized programs the specific shop tasks to be learned and the number of hours an apprentice is to spend on each phase of his shop training are specified in detail. While many companies, especially the larger ones, make an attempt to follow these specific guidelines, the demands of production and other forces in the organization often mitigate against strict adherence to the training specifications.[2,9,20,30]

Detailed lists of related instruction courses to be taken by apprentices in each trade are also characteristic of the more formalized, better-run apprentice programs. And the number of course or credit hours required is usually spelled out in detail. Apprentices may -- and most often do -- take related instruction courses in local public schools. Courses may, however, be offered on company premises or by correspondence. The typical method of instruction is the traditional combination of textbook/workbook and instructor.

Over the years a great deal of thought, work and energy on the part of the Bureau of Apprenticeship and Training, (BAT), state apprentice organizations and representatives of trade associations, industry, labor and education have gone into the development of apprentice training standards and in keeping

course content abreast of technological developments. It is undoubtedly due to these efforts that today one is able to find apprentice programs of excellent quality which are producing first rate craftsmen.(2,30)

SOME EMERGENT PROBLEMS

Despite the success of the apprenticeship movement in general, recent research has indicated that a substantial number of local apprentice training programs are either of relatively poor quality or are failing to achieve the level of effectiveness of which they are capable. This may be due in part to the way in which some local programs are administered.

In his 1969 study of apprenticeable trades, Alfred S. Drew of Purdue University found that

> ... certain elements and principles give apprenticeship its strength; many of these elements are known; but the weak link of apprenticeship lies in the failure to administer, coordinate, control -- in general, to put into practice -- the principles and elements efficiently and uniformly.(9)

To a considerable extent, however, it grows out of the traditional, unchanging training philosophy and methodology that characterizes the apprenticeship movement.

That classical apprenticeship training is so firmly anchored in tradition may simultaneously represent both one of its greatest strengths and its greatest weakness. The fact that apprentices receive most of their practical shop

training (theoretically, at least) from competent, skilled journeymen makes for considerable training flexibility, particularly in trades in which there is wide variation in products and manufacturing processes from one company or industry to another. It is difficult -- although not impossible -- to standardize shop training when such training occurs through the medium of a constantly changing succession of production jobs. The system, as it now operates, provides for both flexibility and for continuity of skill development from one generation to the next.

Despite the inherent strengths and past achievements of the apprenticeship movement, this tradition oriented approach has served to some extent to feed upon itself and to impair the responsiveness of most apprentice training programs to: (1) rapid variations in the numbers of skilled workers needed by industry, (2) the advantages of modern educational technology, (3) the developing problems of minority employment that have become visible as a result of the civil rights movement, and (4) the increasing need of industry -- as demonstrated in every recent study -- for both specialists and all-around craftsmen.[1,9,15,16,33,35]

During the 1960's American industry and government began purposefully to explore the new educational technology and to ask how it might be applied to problems of employee training. New methods of system analysis and task analysis

were being combined with emerging developments in the behavioral sciences and with practical applications of the basic principles of learning. The concept of a new type of training system, based upon task analysis and behavioral objectives, focused attention more sharply on the development of job performance rather than on training or curriculum requirements. Newly developed individualized instructional techniques were suggesting strongly that individual differences in learning ability among trainees were, in fact, an asset rather than the liability they had been -- and still are -- under the more traditional instruction in which whole groups must move at the same rate. As such methods improved learning performance they also raised serious questions about the adequacy and validity of many of the standardized (group normed rather than criterion-referenced) aptitude and achievement tests so widely used in schools and industry.

Under the expanding influence of this new training philosophy, similar movements in a number of foreign countries, the economic pressures of an anticipated shortage of skilled craftsmen and the relentless pressure of Affirmative Action programs and the civil rights movement, a number of private and governmental organizations in the United States began serious studies of the effectiveness, administration, financing, recruitment, selection and training methods of a wide variety of technical and apprentice training programs. The majority of these studies were evaluative in nature and most of

them dealt with the economics of skilled manpower utilization. There were a number, however, which dealt in whole or in part with training and selection methodology.

Since this report deals with methods of training, we will consider primarily those studies that have dealt with this aspect of apprenticeship, and more specifically, those that investigated industrial as opposed to construction trades apprenticeships. The latter involve problems and practices that are peculiar to the nature of the construction industry and which go beyond the variables investigated in this study.

It should be emphasized that the comments and criticisms that have emerged from recent studies and which are discussed below are not intended in any way to derogate apprentice training programs or practices. The author is well aware of and has considerable respect for the vital role the apprenticeship movement has played over the years in the industrial and technical accomplishments of this country. The comments are offered as part of a genuine search for ways to modernize and improve apprentice training and to make it maximally responsive to the changing needs of American society and industry.

Without doubt the most current, far-reaching and comprehensive research program on apprentice training in the United States is that created and supported by the Office of Research and Development (ORD), Manpower Administration, U.S. Department of Labor. During the past eight years the Office

of Research and Development has sponsored more than twenty separate studies of virtually every aspect of apprentice training in U.S. industry. A number of these studies have had or, we hope, will have considerable impact on U.S. manpower policy. Some have led to a variety of action programs such as the MDTA programs and the preapprentice training programs conducted by the Workers Defense League in New York City and by the Urban League in a number of locations.

The pioneering study of the Negro in apprenticeship by F. Ray Marshall and Vernon M. Briggs, Jr.[23] led to new government programs to stimulate the acceptance of minority workers in apprenticeship and increased the visibility of the discriminatory role of standardized personnel tests in selecting employees.

The Purdue study conducted by Alfred S. Drew[9] documented many of the already suspected strengths and weaknesses of apprentice training programs and set forth guidelines for an optimum system. It was one of the first studies to recommend a "systems approach" to apprentice training.

Further valuable information emerged from the Horowitz, Hernstadt[16] study of tool and die makers which demonstrated that apprenticeship is but one of many -- and not necessarily the most effective -- pathways to journeyman status. A later study by Swanson, Hernstadt and Horowitz[34] verified some of their earlier findings and delineated in greater detail the

role of related instruction in apprentice training.

During the same period that these ORD sponsored studies were being carried out, the author and his staff at Training Methods, Inc. (TMI) conducted an intensive task analytic study of six apprenticeable trades in a large midwestern manufacturing company. The purpose of the study was to evaluate the existing company apprentice training programs and, through the application of modern educational technology, to redesign them to maximize training and performance efficiency.

Review of the serious studies that have been conducted during the past several years reveals a striking consistency in the findings of these different investigators with respect to the strengths and weaknesses of existing apprentice programs, in the conclusions they draw and the recommendations they have made.

In the interest of clarity and organization it may be useful to consider the findings and inferences from these studies in terms of: (1) the basic objectives and performance standards of apprentice training, (2) selection of apprentices, and (3) training methods in shop and related training.

Objectives: Both research findings and more casual observations reveal several major problems with respect to how objectives are established for most existing apprentice programs. (1) Examination of the apprentice standards set forth in

most labor/management contracts, or those used internally by companies, reveals that in the majority of cases they consist mainly of lists of courses to be taken and number of hours to be spent on each phase of both related and shop training.

Although the BAT and a few other organizations have published shop training requirements, these are general in nature and they specify in detail neither the tasks to be performed nor the quality of performance desired on each task.

Thus, the objectives of most apprentice training programs in the U.S. are stated not in terms of the measurable performance expected of apprentices upon completion of training, but rather, in terms the number of hours they must spend on each phase of shop and related instruction.

The primary emphasis -- and one which fails to utilize fully individual differences in learning ability -- is on a single measure of time (i.e., 4,000 or 8,000 hours) for all apprentices; measured performance appears to play a secondary role. Strauss has reported, as have the Purdue study, the TMI study and virtually every other investigation that, in practice, uniform performance standards are either lacking or are used informally and with great variability.[9,33,34,35]

> I think we should adopt more generally the practice followed in many European countries and in a few trades in this country: before being admitted as a journeyman, an apprentice should be required to pass a comprehensive written and practical test -- perhaps one taking several days ... In any case, related instruction and apprenticeship generally will be made meaningful if apprentices

realize that they must demonstrate a certain standard of competence before being admitted to journeyman status.(33)

Swanson, Hernstadt and Horowitz report that "Firms which sponsor machinist apprenticeship programs do not gather data on performance of apprentices at work."(34)

These findings are consistent with our own observations in the present study and during our 1966-67 TMI studies. In observing or carefully studying more than a dozen different apprenticeship programs we found little evidence of any systematic attempt to measure job performance at any stage of apprentice training. Indeed, the absence of such standardized performance data made it virtually impossible for us to determine, with any accuracy or uniformity, exactly what tasks a metal trades apprentice should be able to perform at the completion of his first year of training.

One organization we know of that is currently making some systematic effort to establish such performance criteria is the National Tool, Die and Precision Machinist Association, and their data were not yet complete and available when the present study was undertaken. Currently, virtually all apprentice programs are based on the traditional concept of holding time constant and uniform and allowing performance to vary.

A number of authors, most notably Bergevin, have expended great energy, if not logic, in attempting to justify the concept of a uniform number of hours for all apprentices. He

claims that since apprentice selection procedures result in great homogeneity in learning rates among apprentices, a single time standard for all is not only justified, but is necessary in order to achieve organized training.[2]

The logic of this argument is at best obscure to anyone who has seen the broad range of ability and experience that is characteristic of present-day apprentice applicants, or who is familiar with the kind of systematic, organized training programs that have been developed using the new individualized training technology that allows training time to vary but demands a consistently high level of performance.

(2) The second problem, and one commented on by most recent investigations of apprentice training methods is the fact that the programs studied were either based on job analyses that were hopelessly out of date or they had been developed based on someone else's outdated job analysis.[9,15,33] In the TMI study we found apprentices taking complete courses designed to develop knowledge and skills (such as slide rule) that were never used on the job. Such armchair curriculum development -- based on what has been traditional practice -- is characteristic of apprentice programs.[35]

This lack of task specification may be the major reason that time is the primary objective in most programs rather than the much more important variable -- measured performance. It is also the likely reason that most investigators have found

written tests in common use in apprentice programs but an almost complete absence of the use of performance tests. Unless the required performance is specified systematically through task analysis, it is virtually impossible to measure its achievement.

(3) The third problem with respect to basic objectives deals with the conflict between preparing trainees to become all-around craftsmen who are capable of performing all the tasks of their trades or preparing them to become specialists who perform only a limited range of the tasks included in any trade.

Every recent study of apprenticeship has identified and discussed this problem as it applies to both journeymen and apprentices. Barocci reports:

> Most important in the compilation of the index was the common complaint by the apprentices of the lack of adequate rotation on-the-job so that all phases of the job were learned. This again points to the fact that all employers do not have a need for the "all-around" skilled tradesman that the system is designed to produce, but rather only for someone who is skilled in the general aspects of the trade and some or no aspects specific to the indenturing employer. This reinforces the now popular notion of the need for flexibility in the system and possibly a separation of the apprenticeship into various phases based on degree of complexity and specificity of the different aspects of the trade.(1)

The fact that a great deal of specialization takes place in modern industry among journeymen and apprentices was also found in the studies by Drew, TMI, Strauss, Horowitz and Hernstadt and by Hardman and Munn.[9,15,16,33,35] Strauss

reports:

> In terms of the individual employer's own selfish interests, the payoff is usually greater for giving apprentices narrow training. The splintering of the crafts and the increasing specialization of craftsmen contributes to both problems: it reduces the willingness of employers to hire apprentices and their ability to provide all-around training.(33)

The consistency with which all of these studies have identified the problem makes it clear that specialization of function among craftsmen in modern industry is a reality with which the apprentice training profession must deal. To continue to ignore that reality and to insist upon trying to make everyone who enters a trade an all-around craftsman may not only be costly and inefficient, it may in the long run do serious damage to the image and status of the trades and impair their usefulness to modern specialized industry.

It is apparent from the results of these studies that many apprentices graduate to journeymen status without ever having mastered or, in some cases, even performed whole groups of the tasks required of an all-around craftsman. This waters down considerably the image and meaning of the term journeyman. Hardman and Munn have this to day:

> The present typical apprenticeship program posture, in the time, money, skills and capability dimensions, takes away from the hoped-for professional image of the apprentices/journeymen and makes recruitment and retention a difficult problem. This becomes evident when the drop-out rate and ultimate disposition is addressed. Most of the drop-outs of these programs find higher paying jobs in related trades rather soon after dropping out. At the present time it would appear, at a 40% apprentice drop-out rate, that the trade is training

> machinists for the general machining industry rather than for the tool, die and precision machining industrial segment.
>
> ... All the studies seem to find a variance in the competencies and capabilities inherent in the term journeyman. This greatly beclouds the industry journeyman image while at the same time raising serious doubt as to the ability of these training programs to complement the manpower policy dimensions of intra-trade vertical and lateral mobility and continuing career ladder opportunities for apprentices and journeymen.(15)

The major argument advanced in favor of developing the all-around craftsman is that he will -- when necessity demands -- be able to move with ease into a different job, company or industry. All of the research evidence so far reported indicates that, while this is in theory a desirable end, in practice it does not happen to the majority of apprentices and journeymen.[1,9,15,16,33,35]

A training program that is flexible enough to allow for the development of different degrees of generality and specialization among craftsmen may have greater utility for both the employer and the tradesman than does the present rigid apprenticeship system. It may be most beneficial in the long run to confine our rigidity to an insistence on uniformly excellent performance and to encourage flexibility in the methods used to achieve that excellence. Indeed, such a flexible plan was advanced by Horowitz and Hernstadt in their study of tool and die makers, and by the author in his redesign of the apprentice training programs for the midwestern manufacturing company mentioned above.[16,35]

Most European countries, at least in part in response to increasing specialization, are far ahead of the U.S. in the development or more flexible apprentice programs. Roomkin reports:

> Last, we note the increasing tendency for apprenticeship training in Europe to be viewed as a series of interrelated stages or modules rather than as one continuous process. Through such a change, training has been made more flexible, that is, more responsive to the needs of employers.(32)

This search for more flexible, more responsive apprentice training is being pursued actively in Britain, Canada, Germany, Switzerland and a variety of other countries. The research results clearly indicate that the time has come for more modern, utilitarian and effective objectives for apprentice training.

Apprentice Selection and Placement: Recent civil rights legislation has focused the cold light of reality on the efficacy, validity and appropriateness of many of the personnel tests and other methods used in the selection, placement and promotion of employees. Under this searching scrutiny many selection programs -- including most of those used to select apprentices -- have been revealed to have little validity in predicting on-the-job performance of employees, and only slightly better validity in predicting grades earned in training programs.

In most apprentice programs the criteria used to select

applicants involve completion of tenth or twelfth grade, acceptable school grades, passing scores on a battery of personnel tests, successful negotiation of an interview and, in some cases, miscellaneous other minor factors. The first three criteria reflect, for the most part, the verbal skill and achievement of the applicant. Research has demonstrated that such verbal measures have little relation to his ability to perform the on-the-job tasks of his trade.(31)

Although little or no research has been done on this specific question, a serious disparity appears to exist, on the one hand, between the level of verbal (or word) skill (as measured by traditional aptitude and intelligence tests) required to perform the tasks of any given apprenticeable trade and, on the other hand, the much higher level required to pass the widely used entrance tests and to successfully complete the classroom training required by most programs.

It is likely that a reasonably high level of numerical, conceptual, perceptual and learning skill is required to perform as a competent journeyman in most of the metal trades. It is likely, however, that a more modest level of verbal skill is required. Thus, the high level of verbal skill required to pass the entrance tests and to succeed in the classroom may be excluding a considerable number of applicants (especially minority group members) whose verbal skills are adequate to become effective journeymen but not high enough to allow them

to gain entry to the program.

Although the study reported here did not deal directly with the problems of apprentice selection, and very little research has been done in this field, it seems clear that what is needed, particularly in view of the requirements of the Civil Rights Act of 1964, are new methods of selecting apprentices that will in fact predict job performance and be equally valid for both whites and minority group members. Recent studies seem to indicate that some form of performance tests may have potential for solving some of these problems. For maximum efficiency and validity the system developed for selecting apprentices -- and for diagnosing training deficiencies -- must grow out of the same task analysis from which the training system was developed.

Training Methods: Although the content of most apprentice training courses has been updated periodically to include technological changes, teaching and learning methods and materials have failed to keep pace with modern developments. Every investigation has commented on the almost complete absence of the new self-pacing, individualized instructional techniques and modern educational technology.(9,33,34,35)

As has already been indicated, individual differences in learning ability among trainees are usually not utilized fully to increase training efficiency. As is true with most conventional training programs, each trainee is required to

spend a standard number of hours in each phase of training regardless of his ability to achieve competent performance in a shorter period.

In virtually all programs time is held constant; quality of performance allowed to vary. Just as in most educational programs, time is constant; grades are allowed to vary.

Since quality of job performance should be the primary objective of any training program, performance standards should be held uncompromisingly constant; time should be allowed to vary (if individual differences in learning ability are to be utilized).

The temporal and conceptual discontinuity between classroom and shop training is the most commonly voiced criticism of existing training programs. It has emerged in every study of apprentice training programs.

Too often, because of the inflexible scheduling of conventional classroom courses, the knowledge required to perform job tasks is available to trainees either in advance of, or long after, they perform these tasks on the shop floor. This is illustrated by a few of the comments emerging from the TMI study:

> The lack of temporal coordination between classroom and on-the-job training prompted some to refer to this aspect of the program as "unrelated training". This lack of coordination was by far the single most prevalent complaint. All apprentices follow the same route through their related training, but each follows his

> own unique path through his shop training. In some cases one never quite catches up to or matches the other. For this reason many apprentices and journeymen question the value of the entire related training program.
>
> In those tasks for which an apprentice is given related training, such training is likely to be taken when he doesn't need it -- either too early or too late. It also indicates that apprentices feel they get no related training for most tasks performed in their trade.
>
> The traditional philosophy that classroom courses should concentrate on theory while shop training covers the practical work creates a discontinuity between the two that impairs the efficiency of both.
>
> The fact that the apprentice follows one temporal path through related training and another through shop training leads to serious lack of congruence between the two phases of the training program.
>
> Some of the required courses are probably unnecessary to the preparation of competent journeymen. Others are too broad and cover irrelevant material. Some of these courses need modification -- others may be taught only to those whose jobs require them and at the time such knowledge is needed.(35)

Such comments have also emerged from the studies by Drew, Strauss and that of Swanson, Hernstadt and Horowitz.(9,33,34)

Most of the shop training received by apprentices is given by journeymen who, while they are competent in their specialities, have little time and no special training, qualifications or aptitude for teaching others. Thus, most of the shop training burden is carried by men who, by their own admission, are ill-qualified to instruct others.

The following comments from the TMI study reflect with reasonable accuracy what other investigators have found:

> Journeymen's availability and their qualifications and capabilities as instructors on the floor is the subject

that elicited a great many comments.

By far the majority of an apprentice's instruction comes from journeymen. Ninety-three percent of the apprentice's training time is spent on the shop floor. He spends nearly two-thirds (60%) of his training time working with and ostensibly being trained by journeymen. In short, journeymen carry the burden for approximately two-thirds of the total training apprentices receive.

That journeymen, who are essentially skilled craftsmen with little or no training in how to instruct others, are qualified or competent to carry such an educational burden is called into serious question not only by apprentices but also by many journeymen. Their comments reflect several conditions which seem to prevail:

1. Journeymen are too busy to give apprentices the type and quantity of shop instruction they need.

2. In many cases they may not be capable of providing the needed training. While they may be expert in their trade, they are not necessarily good instructors.

3. Running throughout the comments received from both the survey and the interviews is a theme reminiscent of the traditional apprentice-journeyman relationship. Apprentices are seen as helpers, not as trainees -- as the low man on the totem pole whose function it is to do the dirty work and run the errands. Further, journeymen think of themselves as craftsmen, not trainers. Some are even unwilling to assume responsibility for training.

The apprentices need and want more effective on-the-job instruction. The study seems to indicate, however, that in reality they often work alone and learn by trial and error. Even when they do work with journeymen, their role is often that of helper, not learner. The quality of the instruction they get apparently varies widely from one journeyman to another and the study data seem to indicate that much of the instruction they get is of the type where they are passively watching rather than actively participating in the learning process. Overwhelming evidence exists that this type of instruction is extremely inefficient, and that far more efficient on-the-job training methods can be developed through the use of some of the newer training techniques.

The sequence in which apprentices are trained also has considerable impact on the ultimate quality of their

training and it received considerable attention from the tradesmen interviewed.(35)

Another problem that has received attention in every recent study is the fact that advanced placement in most apprentice training programs is based on educational or other criteria which are only obliquely related to whether a man can perform the tasks of his trade.

Thus, some men who are capable of performing many of the tasks of their trades are required to take training in areas in which they have already acquired demonstrable competence. This, of course, is a direct result of objectives based on time rather than demonstrated performance.

Finally, apprentices are rarely consulted on the development of training programs in which they will participate and which will have a profound effect on their future careers. Little, if any, career planning is done.

In summary, the major problems and shortcomings of apprenticeship programs that have emerged from recent research studies are as follows:

1. There has been fairly widespread failure to apply systematically the training standards and procedures that have been developed over the years and are recommended by the Bureau of Apprenticeship and Training and other organizations. Thus, much of the training that is done is somewhat haphazard, not very systematic and probably not as

efficient as it could be.

2. (a) The primary objective of most programs is based on training time rather than demonstrated competent performance, the end product of training that should be of greatest importance to both employer and trainee.

   (b) Objectives have, for the most part, been developed on a rational basis rather than through up-to-date methods of job analysis.

   (c) Systematic measurement of job performance to establish both journeyman status and movement from one phase of training to the next is infrequently used and is subordinated to the criterion of number of hours on course.

   (d) There is considerable disparity between the preference -- expressed by most employers -- for well rounded journeymen, and the amount of specialization of job function which actually takes place among both journeymen and apprentices.

3. The tests and other methods and criteria used to select and place apprentices are, in most cases, seriously lacking in validity, overweighted with verbal skill requirements and probably discriminatory where minority group members are concerned.

4. In many programs there is a serious temporal discontinuity between related instruction and shop instruction.

5. Training methods are most often traditional and little

effort has been made to use the newer and more efficient educational technology.

6. Journeymen carry most of the burden of apprentice training despite the fact that the vast majority of them have had no training and possess minimal qualifications in the art of instructing.
7. Apprentices, whose careers are most affected by the training they receive usually have little or no voice in developing the programs in which they will be trained.

It was a serious interest in examining these problems and in finding solutions to them that stimulated most of the recent studies of apprenticeship, including the one reported here, and that prompted a few organizations to try alternative approaches to apprentice and technical training. Out of this search for more efficient training has emerged a number of modern, effective and promising new approaches to apprentice training in both industry and educational institutions. In varying degrees they represent applications of the new training philosophy and techniques.

The program which, in the author's awareness, represents the most comprehensive example of modern training philosophy applied to apprentice training is that at the Ford Motor Company. This new program, developed starting in 1966, is based on a complete, modern task analysis of all major skilled trades. Although hours-on-course is retained as an

outside dimension, movement through the training program is based on task achievement rather than hours spent on a given task or phase of training. This achievement or performance criterion has been agreed to by the union and, since 1970, has been a part of the labor agreement -- the only such agreement in the United States of which the author is aware. The effect of this new approach has been to improve the quality of training and to bring about a drastic reduction in training time. A more detailed description of the Ford program and the others mentioned here briefly can be found in Appendix A of this report.

Another promising new program, one which represents a very promising departure from tradition and which incorporates many elements of modern training philosophy is the new Canadian "block method". Again, consistent with the more effective, modern training approach, the system is firmly rooted in empirical task and occupational analyses of a considerable number of skilled trades in Ontario. Matrices have been developed which profile curriculum "blocks" for both related training and practical shop training. In this program also, advancement is based on achievement rather than time, and each trainee is provided a personal record of the tasks and "blocks" in which he has demonstrated competence -- a record of <u>what he can do</u> rather than the number of hours he has spent. (See Appendix A)

There are a number of other promising programs now being developed or in operation. Appendix A describes briefly the essentials of just two college programs that are based on detailed behavioral objectives and utilize self-pacing individualized instructional methods.

The recently completed demonstration study by Hardman and Munn of the National Tool, Die and Precision Machinery Association is also very important, not because it attempted to apply modern training technology but because it demonstrated that, with only minor modifications in the way apprentices are rotated and trained in the shop, acceptable levels of performance can be reached in approximately one-third the time now required by the widely used time standards. The authors report:

> The results of this study indicate that the present 2,000 hour standard for the first year of apprenticeship programs can be reduced significantly. The learning time parameter indicates that this time-shortened program could be 25 percent of the present time period. A mediated figure would be estimated at approximately 35 percent of the total time ...(15)

It is hoped that the results of the NTDPMA study and the DSC study reported here will not stimulate an attempt to establish time standards of shorter duration than those now in use, nor lead to further research designed to find the optimum time standards for apprentice training. If we have learned no more than one important lesson from all the research studies that have been done and the programs described in Appendix A, that

lesson points clearly to the efficacy of applying to apprentice training the modern systems approach in which the primary objective should be the attainment of measurable competence in job performance and the establishment of uniform standards in which performance is held constant and time is allowed to vary. The research results indicate that such an approach could produce significantly more effective training with less investment of trainee and trainer time.

It is also interesting to note that these new programs satisfy most of the criteria for an "optimum" apprentice training system set forth by Professor Drew in the Purdue study. And in most cases they achieved this without knowledge of the latter's criteria which were not yet published when most of these programs were developed.

Here is a partial list of those criteria of an optimum system:

(a) Training objectives are based on the skills, knowledge, and attitudes needed by journeymen in the trade; results are measured against these benchmarks.
(b) Trainees are recruited from all possible sources.
(c) Recruitment and selection procedures are established on a sound legal base and are made known to the public.
(d) Policy for granting advanced standing to entering trainees with applicable education or experience exists and is universally applied.
(e) Apprentices, journeymen, instructors, and related training personnel participate in executing a fully planned and developed curriculum.
(f) Trade analysis techniques are used to identify course content whether for a national, regional, or single-employer curriculum.
(g) Presentation of subject matter is in best manner to

assure learning and provide for successive levels of achievement.

(h) On-the-job training is correlated with related instruction.

(i) Provision is made for determining achievement levels of trainees in on-the-job training.

(j) Timing of theory and skill training is coordinated in instruction.

(k) Modern teaching tools and techniques are used in all phases of instruction.

(l) Performance standards realistically reflect industrial practice.

(m) Trainee is monitored by single individual throughout all phases of training, and adequate record of his progress and achievement is kept.

(n) Method and frequency of evaluation should meet with trainee's satisfaction.

(o) Teaching is geared to the interests and abilities of the trainees.

(p) A research and development program provides the key to appraising the entire system on a continuing basis.(37)

It seems clear from the foregoing review that not only do most investigators agree on the basic areas where improvement can be made in apprentice training, there is a good deal of agreement also on the goals to be reached and the methods by which they can be achieved. It was this perceived communality of problem areas and potential solutions that prompted the study reported in the remainder of this report.

OBJECTIVES AND METHODOLOGY OF THE STUDY

OBJECTIVES

The major objective of the present study was to demonstrate that, through the judicious application of modern training technology, an effective first year apprentice training program could be developed in which performance is the primary criterion of success and training time is allowed to vary with individual capability. The more specific objectives were to:

1. Fully utilize individual difference in learning ability by allowing each trainee to progress at his own pace.
2. Base progress through the course on demonstrated task achievement rather than number of hours on the course.
3. Enable apprentices with only modest but appropriate verbal skills to complete the program successfully.
4. Require that all apprentices achieve similar high levels of performance in both shop and related training even though some may take more time than others.
5. Increase the efficiency of training by minimizing the temporal discontinuity that now exists in most programs between shop and related classroom training.
6. Explore the relationship between reading and arithmetic achievement and learning rate on the one hand and performance in training on the other.

7. Lift some of the burden of the instructional process from the shoulders of journeymen who have neither the time nor the training to be competent instructors. These men can be trained to manage the training process and can be used to bring their wealth of experience to bear to help trainees refine and polish their performance.

8. Demonstrate that a self-paced, time-variable program results in a significant saving in both trainee time and instructor/journeyman time.

PROCEDURES

To achieve these objectives a number of decisions and procedures were necessary:

1. Select the trade or trades in which to work. Because of the authors previous experience in redesigning training programs for metal trades apprentices, it was decided to confine the study to first year apprentices in the metal trades crafts: machinists, tool and die makers and machine repairmen. Apprentices in all of these trades take a common first year curriculum. The first year of training was selected since the schedule and budget of the project were insufficient to develop more than a one year curriculum.

2. Select the companies or organizations to participate in the study. Several criteria were used in selecting

these companies:

(a) Approval for and willingness to participate in the study had to come from an acceptably high level in the company -- department head level or higher -- as well as at lower levels where participation actually took place.

(b) The local union in the company had to approve and support participation in the study.

(c) The company had to be willing to contribute the time of its own personnel and its facilities to the development and testing of the new training system.

(d) The company had to have plans to hire new apprentices at approximately the time the new training system was ready for implementation.

(e) Finally, the company had to be willing, if necessary, to allow its trainee group to be divided into experimental and comparison groups in order to compare training results of the new program with those produced by more conventional training methods.

Eight companies were approached to participate in the study. Of these, one decided not to participate, two had no plans to hire new apprentices and five agreed to participate. Two of these are major farm implement companies, one is in the recreation field, one in the food industry and the last is an automobile manufacturer. In the aggregate these five companies committed a total

of 152 apprentices to the study.

Two companies ultimately were unable to participate because, at the time we were ready to implement the experimental PBAT program they had no new apprentices in the trades in which we were working. The field test of the PBAT program, started at a time (September, 1972) of general economic uncertainty and a number of companies had seriously curtailed the hiring of apprentices. The loss of these two companies seriously curtailed the number of black and Spanish speaking subjects available to us.

Ultimately, in order to increase the number of PBAT subjects from minority groups, a class of 18 MDTA trainees was obtained who were taking a course at the Westinghouse Area Vocational School in Chicago that was comparable in shop training to that given to our first year apprentices.

3. Completion of the Task Analysis. Since movement through the PBAT program was to be based on demonstrated task achievement rather than hours on course, the starting point of the system had to be an analysis of the tasks normally required of first-year metal or machine trades apprentices and trainees. Such a task analysis had already been partially completed by the author and his associates in 1967 as part of a project to redesign the apprentice training programs at a large manufacturing

company.

At that time a review of the pertinent literature revealed that although a number of theoretical approaches to task analysis had been developed, very little had been done on the practical application of these concepts. Since our interest was in redesigning training systems, we developed a method of task analysis that was similar in concept to that initially set forth by Miller and Folley.[10,11,12,24] Their methods were developed primarily for use in designing training systems and, as such, were more appropriate for our project than were other schemes which were developed for use in test development, job design, industrial engineering, wage and salary administration or other areas.

While most people think of task analysis as the development of a descriptive list of tasks to be performed by a specific employee or group of employees, such task descriptions are but the starting point of task analysis. For our purposes task analysis is a process, not an end product. It begins with task description and ends with a set of behavioral specifications that can be used for the development of a training or performance development system.

In our initial task analyses in 1967, the following information was gathered:

1. Complete list of all major tasks and sub-tasks performed by journeymen in specific trades.
2. The stimulus conditions under which, or in response to which, each task is performed.
3. When and how often each task is performed and the sequence of performance.
4. Qualitative and quantitative task performance standards, sometimes called feedback.
5. The knowledge, skill and aptitudes required to perform each task.
6. The nature and difficulty of the cognitive and perceptual learning processes involved in learning to perform each task.
7. Tools, equipment and materials needed to perform the task.
8. The average amount of time required to learn to perform each task with acceptable competence.

These data were gathered through intensive interviews, job observations and task survey questionnaires and they had a high degree of reliability when first collected. It was necessary, however, at the beginning of this project to up-date the data and to focus only on the tasks performed by first year apprentices in the metal trades -- rather than on the full range of tasks required of journeymen.

To accomplish this, additional analyses were carried out in selected plants of the companies that were cooperating in the study. This analysis revealed that, in these plants, first year apprentices used a total of 55 tools and measuring instruments and performed an average of 170 major tasks on the shop floor.

Once this task list had been completed a competent foreman performed each task under our observation. While performing each task he also recorded on sound tape a complete description of what he was doing and answered questions about the covert non-observable behaviors involved.

The result was a complete record of the behaviors involved in the performance of each task and sub-task required of first year apprentices in learning to set up and operate the four basic machine tools: mills, lathes, drills and grinders.

4. Development of Behavioral Objectives. Based on this analysis a set of 185 behavioral objectives were written to cover the knowledge and cognitive skills required to perform competently. These objectives covered the domain normally covered in related instruction. These objectives are set forth in Appendix B.

In addition, 153 behavioral objectives were written

covering all the tasks performed by first year apprentices on the shop floor. These can be found in Appendix C.

Initially, these behavioral objectives were expected to apply to all companies included in the project, and they were to cover only the tasks required of first year apprentices. We encountered some minor problems resulting from variations in practice from one company to another and from the inevitable weight of accustomed practice.

We found that one company used the shaper but the others had abandoned this machine and no longer required apprentices to learn how to operate it. We also found that none of the companies normally assigned first year apprentices to the O.D. grinder. Accordingly, these machines were eliminated from the program.

Although our task analysis indicated decisively that apprentices were virtually never required to use trigonometry during their first year, most of the companies insisted that it be included in the experimental curriculum, largely because they had always taught it in the first year and they felt uncomfortable with a training program that excluded it. And this despite the fact that most apprentices have forgotten how to use it by the time it is required of them on the floor -- usually sometime during the second or third year. As a result,

we included an introduction to trigonometry in the mathematics module.

5. Development of Performance Tests. Based on the behavioral objectives, a series of 17 paper-and-pencil performance tests was constructed which covered the domain of, and measured the level of achievement of the 185 related instruction objectives. The same tests were used both as pretests (called Review Exercises -- see Appendix D for samples) to measure the entering behavior of trainees, and as post-tests (called Achievement Exercises) to measure achievement of the behavioral objectives.

   The tests covered the following areas:

   1. Identification and Use of Basic Hand Tools
   2. Linear Measure and Fractions
   3. Micrometer Instruments and Decimals
   4. Basic Industrial Mathematics
   5. Vernier and Dial Instruments
   6. Reading Engineering Drawings
   7. Layout
   8. Metal Cutting Fundamentals and Speeds and Feeds
   9. Work Holding Devices -- Slotted Table
   10. Milling Cutters
   11. Lathe Work Holding Devices
   12. Lathe Cutting Tools

13. Twist Drills I
14. Sharpening Twist Drills
15. Threads and Taps
16. Reamers, Countersinks and Counterbores
17. Grinding Wheels

These 17 criterion tests cover the technical domain that is normally covered in the typical first year curriculum: math, blueprint reading and shop theory. Some companies included such courses as economics, communications, human relations, slide rule, etc. in their first year curricula. Although we view such courses as desirable, we classify them as electives rather than as essential to the immediate development of competent job performance. Since the project was concerned with technical job performance, we did not include such courses in the related instruction series.

In addition to the related instruction tests, 31 audio-visual shop training modules were developed which functioned both as training modules and as performance tests. (This series is described in detail in section 6 below.) Twenty-two of these modules required the trainee to cut metal -- to make a part -- as opposed to the orientation modules (1 through 5, 13, 26 and 30) which did not. For each of these 22 modules a Training Assignment Sheet was developed which gave the trainee the information he

needed to complete the assignment. (Samples of these forms are found in Appendix E.) These sheets also required the trainee to record the end product of the judgments, decisions, calculations he had to make to complete the assignment (i.e., speeds and feeds, tolerances, depth of rough and finish cuts, etc.). The completed assignment sheet taken together with the workpiece produced -- without the aid of the A/V training module -- constitutes a complete criterion performance test record of what a trainee is capable of doing. If a trainee could pass the test, according to the performance standards set forth in the behavioral objectives (see Appendices B and C), he had achieved the criterion for that set of objectives.

6. Development of the Training Modules. With the behavioral objectives and performance tests completed, it was now possible to develop the PBAT training modules. To fit our training design they had to meet certain criteria:

   (a) They had to be self-instructional and self-pacing to minimize instructor time and to capitalize on individual differences in background and learning rate.

   (b) If the tasks covered required performance rather than simply verbal responses, the modules and their accompanying achievement tests also had to require performance. Thus the tests required trainees to

measure objects with measuring instruments, to sharpen lathe cutting tools and drills, to actually do a layout on metal and to make parts on machine tools.

(c) The PBAT modules had to cover discrete subjects, and be short and independent enough of each other so that trainees could complete them when they needed the skills they taught. This flexibility was increased by combining some subjects. For example, even though fractions and decimals were taught in the mathematics module, they were also included in the measurement modules so that a trainee could learn enough about decimals from the micrometer module to be able to complete it without having taken the math module.

(d) The printed related instructional modules had to be written at a reading level that would make it possible for trainees with sixth or seventh grade reading skills to complete them successfully. This was accomplished both by reducing the amount of reading material through the use of several thousand illustrations and by writing at approximately the sixth grade reading level.

(e) The PBAT audio-visual shop training modules had to be developed so they could be used at the machine on the shop floor by trainees with no prior experience and with little or no help from an instructor. Thus

they had to provide complete step-by-step instructions not only on how to machine metal, but what to do when an error was made or something went wrong. In an attempt to minimize materials development time and costs a search was made for commercially available printed and A/V materials that would both meet the criteria above and cover the domain of our behavioral objectives. More than 50 printed programs and workbooks were reviewed. Only two were found to meet the criteria. A semi-programed mathematics book developed by Dow Education Systems and published by McGraw-Hill, Inc. was used as module 4 in the related instruction series. Reading Engineering Drawings published by Xerox, although somewhat general, met most of the criteria and was adopted as module 6. The other 15 PBAT related instruction modules were developed by the DSC staff. They include approximately 600 pages of self-instructional material. The pretests and post-tests were also developed by the DSC staff.

In addition, a Metal Trades Achievement Exercise was developed consisting of 150 criterion problems drawn from the 17 module tests. This test was used as a first year final exam for the comparison group and as a follow-up test with one of the PBAT groups.

The audio/visual shop training modules consist of 735

photographic slides (35 mm) and 27 sound tapes. They are used in a Kodak Carousel 35 mm slide projector together with a manually operated cassette tape recorder and headset. The slides are projected on a 14" x 14" portable rear screen device. The entire A/V set-up is mounted on a table or bench and used at the machine on the shop floor. (See photographs on next page.)

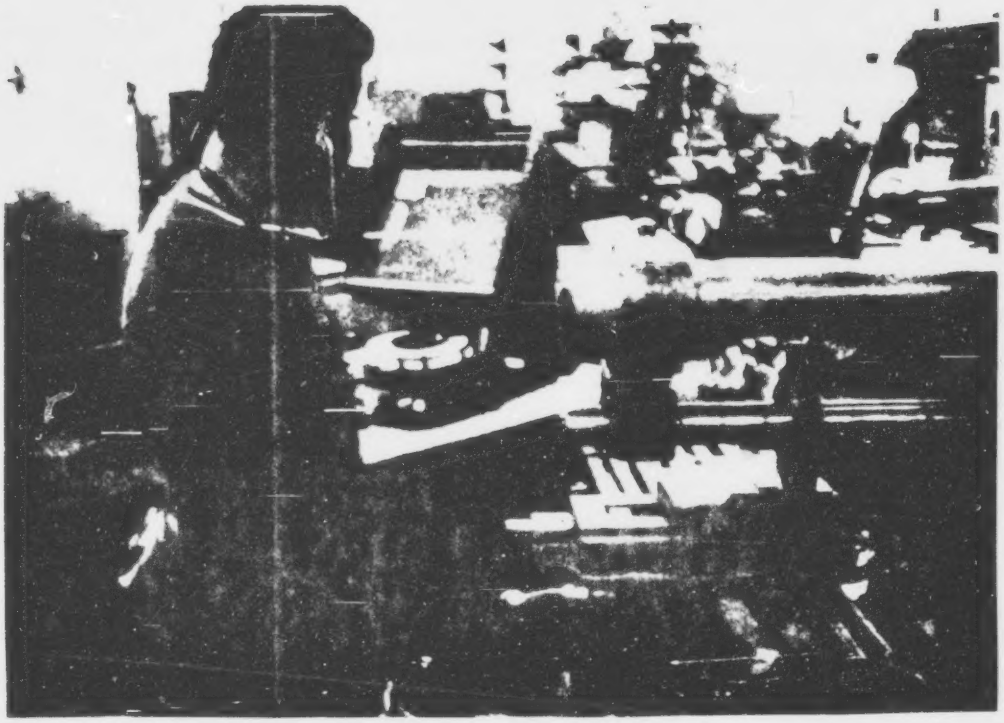
The complete series consists of the following modules:

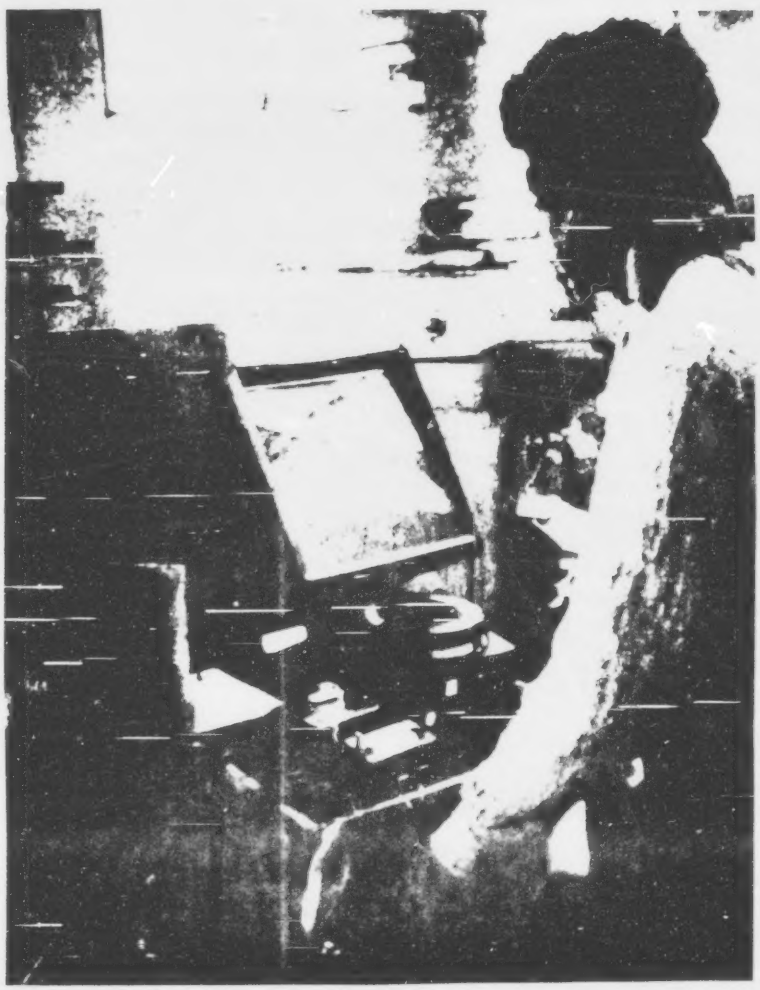
Milling Machine

1-4. Introduction to the horizontal milling machine
5. Introduction to the vertical milling machine
6. Plain (slab) milling
7. Side milling a slot
8. Form milling a radius
9. Sawing a slot
10. Face milling
11. End milling a closed end slot
12. End milling a pocket

Lathe

13. Introduction to the engine lathe
14. Facing
15. Turning to a shoulder
16. Taper turning with the compound
17. Parting and grooving
18. Chamfering





AUDIO/VISUAL TRAINING MODULES BEING USED BY TRAINEES IN THE SHOP AT A MILL (above) and A GRINDER (left)

19. Drilling and centerdrilling

20. Boring

21. Reaming

22. Filing and polishing

23. Knurling

24. Taper turning with attachment

25. Cutting threads

Drills

26. Introduction to drills

27. Drilling, counterboring and countersinking

28. Reaming

29. Machine tapping

Surface Grinder

30. Introduction to the surface grinder

31. Truing and squaring

As the PBAT training modules were being developed they were tried out on an individual basis using naive subjects to ensure that the learning sequences were complete, understandable and usable. They were also reviewed by subject matter specialists for content accuracy.

In addition to the audio/visual training modules, Shop Work Assignment Forms were constructed. (See Appendix F for samples of forms.) Once an apprentice had completed the A/V sequence on a particular machine

(i.e., the lathe) he was to be given three or four regular work assignments that came through the shop. These would require that he apply the skills he had learned to an actual job. He was required to enter on the form much the same information he had entered on his Training Assignment Form: (1) type of operations to be performed, (2) type of work holding device he used, (3) tolerances, (4) type of cutter to use, (5) number and depth of cuts, (6) speeds and feeds he would use.

His performance on the machine, the quality of the part he produced and the accuracy of his judgments and calculations were rated by an instructor or journeyman and the time it took him to set up and complete the job was recorded together with the amount of journeyman supervision required. The form also asked the journeyman or foreman to estimate how long it would take a competent journeyman to complete the job.

The purpose of this procedure was to test the efficiency with which apprentices could apply to actual jobs coming through the shop and what they had learned from the A/V modules. These assignments functioned as criterion tests of the teaching effectiveness of the experimental PBAT program.

Later in the study, since we could find no established criteria of what a 2,000 hour apprentice should be able

to do, we used these forms to evaluate the performance of the subjects in the comparison group. Thus, the complete PBAT system consisted of:

17 Printed self-instructional related training modules
17 Achievement tests
1 Metal Trades Achievement Exercise
31 Audio-visual shop training modules
22 Training Assignment Sheets that could also be used as shop performance tests
12 Shop work assignments
1 Apprentice master achievement record
1 Manual of Administration

For a complete description of how the system worked in operation see pages 59 and 60.

To check the reading level of the PBAT related instruction modules, a group of MDTA trainees for unskilled jobs was provided us by the Hotpoint Division of the General Electric Company. This group of Puerto Rican and black trainees had no previous experience in the subject areas tested and had reading skills ranging from grade 6.5 to grade 9.1. Their arithmetic skills ranged from 6.5 to 8.3. These skill levels were determined through the use of the Survey of Reading and Arithmetic Achievement tests published by the California Test Bureau.

In the course of this initial test of the materials (an observer sat with each small group of four trainees) a

tendency was observed among trainees whose reading level was sixth grade or below to try to avoid reading. They were ingenious at getting others (other trainees or the observer) to either help them read or to read for them. Their typical approach was to try to solve a problem -- both in the programed modules and the criterion tests -- without first reading the small amount of material required -- often no more than a single sentence. When they were directed to go back and reread the problem they were most often able to solve it. But their reading consumed an inordinate amount of time. Our observations indicate that adult trainees who read at sixth grade or below may have developed lifelong reading avoidance habits, perhaps due to their inability to master the reading material encountered in their every-day lives. These people tend to arrange their lives so that most of their learning is accomplished through listening. Additional evidence of this emerged from the research of HumRRo on the relation between job performance and such variables as literacy, aptitude and job experience. Among other things, they found that the reading grade level of Army training manuals was several grade levels above the average reading ability of the trainees using the manuals. Anyone who has had much experience with industrial training is aware that this situation prevails also in far too many industrial training programs including apprenticeship programs.

They also found that the groups with low reading skills preferred to learn by listening rather than reading. Interestingly, we found that when the materials were read to these MDTA trainees, they were, for the most part, capable of learning the concepts. Their learning deficiency appeared to be one of reading, not of conceptualization.

Because of the reading avoidance reaction encountered with this group, we decided to confine our field test, if possible, to apprentices who read at seventh grade level or above.

The results of this initial test were promising despite the reading problems encountered. Listed below are the data for this group.

Module	Learning Time (minutes)	Pretest Score %	Post-Test Score %
Linear Measure	150	29	77
Micrometer	120	63	94
Verniers	150	5	87
Hand Tools	35	53	80*
Drills	150	32	50*
Threads & Taps	75	27	95
Reamers	60	24	90

*When scores of sixth grade readers were excluded these became 86% and 77% respectively. The mean score increased to 86.5%.

This small initial test indicated that the reading level of the materials was suitable for our purposes and that they were capable of producing acceptable levels of learning. Accordingly, the remainder of the PBAT modules were developed and pretested.

7. Design of the Study and Subjects

Design of the Study. Because of economic, administrative and other practical restrictions encountered in industry, it is usually impossible to conduct a carefully controlled training experiment in an industrial setting. Hiring freezes and schedules, inability to control the applicant pool, the demands of production and a host of other factors mitigate against being able to construct experimental and control groups in which each member of one group is matched with a member of the other group.

Such was the situation in September, 1972 when we launched the field test of our experimental training program. We had hoped to be able to have 60 subjects go through the experimental PBAT training program, about 20 of whom would be minority group members with limited reading skills. We would then be able to compare their performance with that of 60 other subjects who were, at the same time, going through conventional apprentice training programs.

Unfortunately, the field test came at a time of economic

uncertainty when the participating companies were seriously curtailing the hiring of apprentices. One company, which was to supply 75 apprentices, could provide only 23. Another which had promised 25 apprentices, and from which we had expected to get most of our minority group members, was unable to supply none, as a result of a company-wide hiring freeze. Essentially the same situation existed in all the participating companies with the result that, from these companies, only 29 trainees could be found for the experimental group. And this group included only 3 minority group members.

To compensate for this attrition, especially of minority group members, an MDTA class of 18 from the Westinghouse Area Vocational School in Chicago was added to the experimental group. These people were in a pre-apprentice training program that covered virtually the same ground that is covered by both the first year of metal trades apprenticeship and by our experimental curriculum. In addition, they were mostly blacks and at first we thought that we had found the disadvantaged group with low reading achievement that we had expected from one of the companies. This, unfortunately, turned out not to be true; their reading and arithmetic scores were considerably higher than we had anticipated. They had an average reading grade level of 8.4 and a 9.3 average arithmetic grade level. Only about 20 percent of the group was

reading below eighth grade level.

In total the PBAT group contained 47 trainees. Not as many as we had anticipated, but considerably more than the economic conditions of the time seemed to herald.

Despite the adverse economic conditions, it was possible to acquire a comparison group of 40 subjects all of whom, at the time their skills were tested, had completed from 388 hours to 2,300 hours of conventional metal trades apprentice training. Twenty-three of these were provided by a large automobile manufacturer, the other 17 by one of the farm implement companies.

Because of time and scheduling constraints it was not possible to administer pre and post-tests to the comparison subjects. Instead, they were given the Metal Trades Achievement Exercise as a measure of achievement in related instruction. Their performance on this test could then be compared to the performance of the experimental group on the same test items.

Since the comparison subjects did not start shop training at the same time as the PBAT subjects two indirect approaches were necessary. The training time and performance of the PBAT group could have been measured against the average standard performance required of apprentices who had just completed their first year

(2,000 hours) of training. While this would have been a desirable and expedient method, we discovered that such standards for shop performance do not exist. Or if they do exist, we were unable to locate them. As mentioned in the first chapter of this report, virtually every investigator has found that no systematic measurable performance standards for shop work exist for either journeymen or apprentices. Thus, we could not measure the shop performance of our PBAT group against a known standard.

An indirect approach to this measure, however, was to take the Shop Work Assignments that our PBAT group subjects had successfully carried out after they had completed their 39-1/2 hours of A/V shop training. By comparing the time needed to complete these assignments with foremen's estimates of how long it would take a competent journeyman and a 2,000 hour apprentice to complete these actual work assignments, it would be possible to compare the efficiency of our PBAT group after approximately 40 hours of instruction to the estimated performance of these two much more experienced groups.

Accordingly a group of 18 foremen in six plants were asked to make estimates of how long it would take an average 2,000 hour apprentice and a competent journeyman to complete each assignment.

A second method used to approximate performance standards of first year apprentice (those with varying amounts of time on course) was to ask the foremen who supervised the comparison group apprentices to rate the performance of their apprentices on the same machine performance tests taken by the PBAT group during the course of their shop training. These foremen estimated, on a four point scale, the performance of the comparison group members whose work they supervised on 14 of the 22 shop performance tests. Samples of these performance tests are in Appendix E and the form used to rate each apprentice is in Appendix G.

In summary, the statistical comparison made between the PBAT and comparison groups are as follows:

	PBAT Group	Comparison Group
RELATED INSTRUCTION:	Scores on Module Achievement Tests	Scores on Metal Trades Achievement Exercise
	Time to Complete Experimental Program	Total Time on Course and in Conventional Related Instruction
SHOP TRAINING:	Instructor's Ratings on Shop Performance Tests	Foremen's Estimates of Performance on Shop Performance Tests
	Time to Complete Shop Assignments	Foremen's Estimates of Time to Complete

In addition, the PBAT and comparison groups were compared

on amount of instructor time required. Further, comparisons were run, for the PBAT group only, between arithmetic and reading skills and performance in both shop and related training.

Subjects. The subjects in the experimental PBAT groups all were in two or four year apprenticeships (not necessarily BAT registered programs) in the metal trades, with the exception of those from the Westinghouse Area Vocational School. Virtually all graduates of this program go on to the second year of apprenticeship in private industry. Regardless of what they are called, (in one company, for example, people in the two year machinist course are called trainees) they were all taking a common curriculum. The following table summarizes the demographic characteristics of the 46 men and one woman in the PBAT group.

PBAT GROUP

	Median	Range
Education (grade	12	9-16
Shop Courses Taken	1	0-6
Math Courses Taken	2	1-6
Reading Achievement*	10.1	5.6-13.6
Arithmetic Achievement*	10.8	6.5-14.8
XAP68 Pt I**	96%	78-100%
XAP68 Pt II**	91%	63-100%

*The tests used for these measures were the Surveys of Reading and Arithmetic Achievement, Junior High Edition, published by California Test Bureau.

**This is the designation of the experimental test that was developed by the U.S. Civil Service Commission. Part I deals with reading comprehension. Part II deals with shop math.

Ninety-one percent of this group had completed twelfth grade or beyond. Less than half had taken shop courses before starting training, three had completed a few months of apprentice training in welding and auto mechanics, and only six had attended a vocational school. Thirty-six percent came from minority groups (13 blacks and 4 Puerto Ricans). Only one out of eight of the group had reading skills below grade 7.5 and only 6 percent had arithmetic skills below that level. The arithmetic and reading skill levels of the PBAT group were sufficiently high that the XAP68 experimental test was of little use. Eighty-nine percent of the group scored 90 percent or better on the reading portion of the test and 67 percent had comparable scores on the shop arithmetic part of the test. With such extreme restriction of range it is usually difficult to correlate scores on the test with any other measures.

The XAP68 was designed for use with members of disadvantaged minority groups. We were, unfortunately, unable to attract the type of applicant whose skills would have been appropriate for this test. Even the companies that were willing to recruit and hire applicants with such low level skills were unable to attract such people at the time we needed them. In view of the restricted range of scores on this test, only one analysis was carried out. (See table on page 72.)

Comparison Group

The subjects in the comparison group were selected by the companies using their normal selection procedures. Unfortunately, time and administrative constraints made it impossible to collect reading and arithmetic or XAP68 test scores on the comparison group subjects.

The group of 40 consisted of 4 blacks and 36 white apprentices, 39 men and one woman. The median education level of this group was twelfth grade and, except for the amount of training they had, there were no significant differences in background between the comparison and the PBAT groups. The group consisted of machinist, die maker, toolmaker and machine repair apprentices in both two year and four year training programs.

The comparison subjects were selected to represent a wide range of both total number of hours on course and number of hours of related instruction completed. This was done in order to find out if a relationship could be found between performance on the Metal Trades Achievement Exercise (covering the first year of related instruction) and shop performance on the one hand and number of hours on course on the other. Does performance increase with increasing number of hours on course? The distribution of total hours on course and hours of related instruction completed is presented in the tables below.

HOURS OF RELATED
INSTRUCTION COMPLETED

Hours	Percent
Less than 100	18
100 - 199	40
200 - 299	30
300+	12

Mean number of hours of related instruction completed was 187.

TOTAL HOURS ON COURSE

Hours	Percent
Less than 500	20
500 - 999	25
1000-1499	23
1500-2300	32

Mean number of hours on course was 1177.

Examination of these figures reveals a reasonably even distribution of total hours on course with 55 percent having more than 1,000 hours (equivalent of six months on course). The majority of these subjects also had completed more than six months of related instruction. In fact, 67 percent had completed more than the 144 hours normally required of most first year apprentices.

In addition to the PBAT and comparison groups, a

third group of 58 production machine operators was added in order to find out how lower level employees would perform on those related instruction modules that were relevant to their jobs. This group was drawn at random from a larger sample of 300 trainees. Initially the entire group was to be used but time constraints made this impossible.

The background characteristics of the group are listed below.

PRODUCTION TRAINEES

	Median	Range
Education	12	8-16
Shop Courses	1	0-5
Math Courses	2	0-4
Reading Grade	9.5	4.0-14.3
Arithmetic Grade	9.0	4.5-15.0
XAP68 Pt I	92%	34-100%
XAP68 Pt II	74%	22-100%

The members of this group are very similar to the PBAT group in level of education and in number of shop and math courses taken. They possess significantly lower reading and arithmetic skills, however, more than one half grade level in reading and nearly two grade levels in arithmetic.

8. Field Administration. In each organization that parti-

cipated in the study one person was designated as the administrator. This was usually a member of the training or personnel staff. The administrator was provided with a complete manual of instructions and all the printed materials and A/V programs and equipment needed to carry out the program.

Although we recommended, in our instructions to participating companies, that an intensive training schedule be followed (1/2 day of related instruction and 1/2 day of shop instruction until the program was completed), only one company followed that schedule. Westinghouse Area Vocational School also followed it for part of the course. In the second company the schedule was eight hours a week of related instruction and 32 hours a week of shop work. In the third it was even more restricted -- two hours a week of related instruction and 38 hours of shop work.

The administration schedule was relatively simple:

(a) At the first training session the experimental PBAT program and its procedures were explained to trainees.

(b) The reading, arithmetic and experimental U.S. Civil Service tests were administered.

(c) Each trainee was provided with a master schedule on which he kept a continuous record of which modules he had completed. Using this form, each trainee could do his own scheduling thus relieving instructors of the record keeping burden.

(d) Each trainee then took a pretest covering each related instruction module. This was graded by

the instructor but the grade was not revealed to the trainee unless he scored 90 percent or better. In that case he need not complete the training module. If he scored less than 90 percent, he then completed the module and took the post-test. Ideally, and in one company this procedure was followed, if the trainee failed to score 90 percent or better on the post-test, he was required to review the module and retake the test. In that company post-test retakes occurred in about five percent of the cases. Because some trainees scored 90 percent or better on the pretest, there were approximately 10-15 percent fewer grades on the post-tests than on the pretests.

(e) Trainees followed different sequences in related instruction depending on the machine to which each was to be assigned. Men assigned to the milling machines, for example, completed those modules dealing with the mills before they started with the A/V milling machine training sequence. Men assigned to other machines completed different modules.

(f) When a trainee was assigned to a machine, he was provided with a set of Training Assignment Sheets, the A/V equipment and programs for that machine and he proceeded on his own to learn how to operate the machine and to complete the training assignments. (See Appendix E.)

(g) At various points throughout the A/V programs, when he thought he was ready, the trainee called his instructor to administer the performance test or to check the accuracy of his work. The instructor rated the quality and accuracy of the work of each trainee on a special form provided.

(h) When a trainee had satisfactorily completed all the A/V training assignments on a machine, he was given three routine shop assignments to complete on that machine. His performance on these assignments was also rated by his instructor using a special Shop Work Assignment Form. (See Appendix F.)

(i) Each trainee continued in this self-paced, self-scheduled manner until he completed the entire program. He was then assigned to regular shop work.

(j) At the end of the program each trainee and administrator was asked to complete an attitude questionnaire. (See Appendix H.)

The research staff visited the research sites frequently to collect data, discuss problems with the administrators and to answer questions and iron out difficulties.

The major problems encountered were: (1) convincing companies to set up the intensive training schedule recommended rather than the more relaxed schedule usually found in apprentice programs, (2) overcoming the sometimes fanatically tenacious resistance to change encountered -- not among training managers -- but among some instructors and journeymen. This resistance was greatest among personnel who had had limited exposure to new training methods, (3) the difficulty of comparing PBAT and comparison subjects' performance when the two groups were on completely different training schedules.

For example, the trainees who completed our experimental PBAT program -- on a schedule of 1/2 day in related instruction and 1/2 day in shop instruction each day -- completed their first year of related instruction in an average of about 19 days -- 62 hours. Trainees on less intensive schedules (four to eight hours a week of related instruction) averaged only two hours more than that figure but the hours were spread over several months.

If we were to administer our experimental achievement tests to comparison subjects -- going through an appren-

tice program with a conventional class schedule -- after they had completed 62 hours of related instruction, we would find that they would do well in the two or three areas in which they had taken courses, but because their related instruction is spread out over the entire first year, there would be a number of areas in which they would score poorly because they had not yet taken the courses covering these areas. Such a plan would be unfair to the comparison subjects and the results would be difficult to interpret.

Results such as were anticipated are, of course, what emerged. Despite the fact that a high percentage of the comparison subjects had completed more than the normal 144 hours of related instruction and more than 1,200 total hours on course, their coverage of the basic first year training requirements was spotty and unsystematic.

The table below summarizes the percentage of the comparison subjects who had completed courses in each subject and who had any training at all on the four basic machine tools.

	Percent
Related Instruction	
Shop Math	100
Algebra	67
Geometry	38
Trigonometry	23

	Percent
Hand Tools	72
Linear Measurement	69
Micrometer and Vernier	92
Layout	28
Metalurgy	61
Speeds and Feeds	77
Shop Theory	
Mills	51
Drills	90
Lathe	51
Grinders	26
Threads and Taps	79
Reamers, etc.	79
Blueprint Reading	95
Machine Tool Training	
Mills	46
Lathe	36
Drills	61
Grinders	26

Although most had covered the elementary first year subjects, very few had had courses in geometry or trigonometry, layout, mills or grinders. And less than half had had shop training on mills, lathe and grinders. These data point clearly to the lack of uniform training requirements and, as will be seen later, indicate serious lack of training efficiency. This will be discussed at greater length in the next section.

RESULTS OF THE STUDY

In view of the major objectives of the project (see page 29), the most significant results to emerge involve the quality of performance attained by the PBAT group and the time required compared to established apprenticeship requirements. The times required for the PBAT group to complete the entire first year curriculum are presented below.

	TIME IN HOURS		
	Slowest Trainee	Mean	Fastest Trainee
Related Instruction*	107:00	61:52	24:12
A/V Shop Instruction	57:12	39:30	29:42
Total	164:12	101:32	53:54

*Figures include times to complete pretests, training modules and post-tests.

The average apprentice in the PBAT group completed, in 101 hours and 32 minutes, the entire first year of related instruction (in technical subjects required for job performance only) plus basic training in all the tasks he would be required to perform during his first year on the four basic machine tools.

RELATED INSTRUCTION

The 61 hours and 52 minutes, on the average, needed for

related instruction can be compared to the 144 hours of related instruction usually required of first year apprentices. In fact, the coverage of the PBAT curriculum was broader than that usually received by first year apprentices. As pointed out in the prior section, a considerable number of the comparison group trainees did not cover, in their first year, the full range of subjects included in the PBAT curriculum (see table on pages 62-63).

Even the slowest trainee completed the course in considerably less than the standard 144 hours. The faster apprentices were able to finish in such startlingly short time because several who had previous training were able to score 90 percent on a number of the pretests and thus were not required to complete those training modules.

The longer times were due to the fact that some trainees learn at a slower pace and also to the recommended practice -- followed in at least one company -- of requiring trainees who did not score 90 percent or better on the post-test for any module to go back, review the module and retake the test.

The figures leave little doubt that the time required to achieve an acceptable level of performance in related instruction can be considerably less than the standard 144 hours now recommended. This is especially true if the first year curriculum is not burdened -- as some now are -- with irrelevant courses or subjects that trainees will not use until their

second or third year in training.

The key term above is, of course, "acceptable performance". In related instruction this means applying mathematics and shop theory, reading blueprints and using measuring instruments with accuracy, etc. A more detailed look at performance is available from the table on the following page.

Although the 90 percent criterion level was not achieved on all the post-tests, the overall mean achievement level of 85 percent is far above that usually attained in conventional training programs. Many of these scores were reduced by the performance level in one of the participating organizations where the overall achievement level was 73 percent. In the other three organizations involved in the study the overall achievement level was 93 percent -- above the ninety percent criterion.

It may be useful to comment on the apparent reasons for the poor performance in the one organization. The average reading and arithmetic grade levels were significantly lower in this organization than in the others -- ninth grade versus eleventh grade. This would normally be considered a casual factor since related instruction achievement scores were positively and significantly correlated with reading and arithmetic scores. (See below.) In the other organizations, however, there were a number of trainees with lower reading and arithmetic scores and yet the mean overall achievement score of these people was 91 percent.

Subject	Mean Time To Complete In Hours & Minutes	Mean Pretest Score (%)	Mean Post-Test Score (%)
Basic Hand Tools	1:10	67	92
Linear Measure & Fractions	2:45	79	86
Micrometer Instruments & Decimals	2:25	69	85
Basic Industrial Math	13:34	46	73
Vernier & Dial Instruments	1:55	48	76
Reading Engineering Drawings	10:30	78	91
Layout	7:42	87	93
Metal Cutting Fundamentals	5:15	29	82
Work Holding Devices - Mills	3:05	70	97
Milling Cutters	2:10	42	83
Lathe Work Holding Devices	1:48	58	90
Lathe Cutting Tools	3:09	38	85
Twist Drills	1:31	66	87
Threads and Taps	1:34	48	85
Reamers	1:45	58	80
Grinding Wheels	1:32	29	77
MEAN	61:52	57	85

Although we lack hard data to support the contention, we believe the critical causal variable was the quality of program administration and the attitude of one of the program administrators in this organization. The decision to participate in the study was made at a high management level in the organization. One of the administrators was quite competent, intrigued by the PBAT system and very cooperative. This attitude was

reflected in the performance and positive attitude of his trainees. The other administrator, who had been doing the same job for thirty years, was opposed to this new program that had been imposed from above and required him to change his method of instructing. Although he completed the program, his procedures and record keeping were disorganized and it was necessary to visit him very frequently to insure the program was completed. His negative attitudes filtered down to his trainees and their performance was considerably poorer than any other group in the study.

Even in a self-paced, self-instructional program such as the PBAT, the competence and attitudes of the program administrators are critical if high level performance is to be achieved.

A further comparison can be made between the related instruction performance of the PBAT group and that of the comparison group. Since it would have required more than ten hours to administer them, it was impossible to have the comparison group take all 16 of the module post-tests. For that reason they were administered the Metal Trades Achievement Exercise (MTAE), a shortened, 2-1/2 hour version of these module tests. The MTAE was administered to the comparison subjects at varying points during their first year of training. The range of total hours on course was 388 to 2,300 hours, with a mean of 1,176 hours. The range of hours of related instruction completed was 66 to 304 hours, with a mean of 189 hours.

The results for the two groups are presented below.

RELATED INSTRUCTION PERFORMANCE
OF PBAT AND COMPARISON GROUPS

	PBAT Group	Comparison Group
N	47	40
Mean	85.7%	59.6%
Range	53.0-97.6%	28.4-80.7%
s.d.	11.9	10.7
t	10.6	
p	.01	

The overall mean achievement score of the PBAT group was significantly greater than that of the comparison group. But, the former had taken the performance tests immediately following training in each module, while the comparison subjects had taken the test from three to nine months following training in some courses.

To determine the effect of this time lag two groups of 19 PBAT trainees were given the MTAE from three to nine months following the completion of their training. This group had a mean of 750 total hours on course and 185 hours of related instruction. The results of this comparison are as follows.

COMPARISON OF MTAE SCORES
OF PBAT AND COMPARISON GROUPS

	PBAT Group	Comparison Group
N	19	40
Mean	77.2%	59.6%
Range	55.8-90.0%	28.4-80.7%
s.d.	9.9	10.7
t	6.05	
p	.01	

Despite the time lag, the PBAT group outperformed the comparison group to a significant degree, and with a mean achievement score only 10 percent below that achieved (85.7 percent) immediately after the group completed training. The experimental PBAT program not only produces high levels of performance in related instruction, the knowledge and skills developed are relatively resistant to deterioration over this short time.

One further check was run to determine whether comparison group scores on the MTAE vary with number of hours of related instruction completed. The rank-order correlation between these two variables is .06 (not significant). There appears to be little, if any relationship between achievement and time spent, at least within the range of hours completed

by this group (66 to 304). This result, although based on a small number of cases (40), is consistent with the findings of Hardman and Munn and of Rigby and Eiffert. It is axiomatic and perhaps redundant to reiterate that the quality of what takes place during each hour of training rather than number of hours is the critical variable in determining level of post-training performance.

It is this single, obvious fact that argues most eloquently for training programs in which performance outcome is the primary criterion and time is allowed to vary. In virtually every study of self-paced training reported in the literature, the average number of hours required to complete the course is significantly lower than the total time required in comparable conventional, fixed-time courses.

Concentration on fixed-time as the primary criterion may often lead to a preoccupation with number of hours rather than what happens during and, more important, after those hours of training. This misplaced emphasis is common in both training and education programs and is traditionally characteristic of most apprentice programs.

To explore further the factors that were associated with related instruction performance, product-moment correlations were run between the latter and scores on the XAP68 test (the U.S. Civil Service experimental test), reading and arithmetic grade levels. The results of these analyses are presented

in the table below.

RELATION BETWEEN TEST SCORES AND PERFORMANCE IN RELATED INSTRUCTION

	Mean	s.d.	r*
Arithmetic Grade Level	10.8	2.3	.81
Reading Grade Level	10.1	2.5	.47
XAP68 Shop Math	91.7%	8.5	.48

*All these coefficients are significant at the .01 level.

No correlation was run between performance and scores on the reading part of XAP68 because 89 percent of the apprentices scored 90 percent or better on that test. The test was obviously too easy for this group and no correlation could be expected with such restricted range.

The figures above indicate that, for this sample at least, these three tests are capable of predicting with acceptable accuracy, performance in related instructions. Further, arithmetic scores appear to be more effective than reading scores as a predictor of performance in related instruction. This result may in part be a function of the type of training materials used in this program. Since reading skill requirements were minimized -- (the materials were written at

the 6-7 grade level) -- arithmetic skill may have a proportionally greater weight in predicting performance.

It was pointed out above, however, that low scores on these tests do not necessarily preclude the possibility of high levels of training performance. It seems likely that, given (1) training materials that do not require high levels of verbal skill, (2) which allow each trainee to proceed at his own best pace and (3) effective administration of the program, even those trainees whose reading and arithmetic skills are poor may be able to succeed. In this study there were ten men whose reading and arithmetic scores were at sixth and seventh grade levels. This group of 10 had an average achievement score in PBAT related instruction of 76 percent. And as pointed out above, those in the effectively administered programs achieved mean scores of 91 percent.

This phenomenon was also observed among a group of lower level production machine operator trainees at one of the participating companies. The table below illustrates how this group of 58 trainees compares to the experimental group.

	Production Trainees	Experimental Group
Mean Reading Grade	9.5	10.1
Mean Arithmetic Grade	9.0	10.8
XAP68 Shop Math	74%	92%
Related Instruction Achievement-Mean	82%	86%

The reading and arithmetic skills of this group are significantly lower than those of the experimental PBAT group. And yet, their average achievement in related instruction was not significantly lower.

A small sub-group of nine trainees had reading and arithmetic skills at the sixth and seventh grade levels. The mean achievement score of this group was 78 percent. Our observations lead us to believe that the critical variable was the care and systematic attention to detail with which this program was administered. There is a point, however, beyond which careful administration seems to have little impact. A second small group with reading and arithmetic skills at the fourth and fifth grade levels were able to score only an average 62 percent on the achievement tests. The 6-7th grade level may be the floor below which acceptable performance cannot be expected, even with instructional materials such as were prepared specially for this project. Further research will have to clarify that point.

SHOP INSTRUCTION

One of the most difficult problems in evaluating the shop performance of the PBAT group is the absence of a criterion against which to measure it. As already indicated, no specific behavioral standards of shop performance are available for 2,000 hour metal trades apprentices. Number of hours completed is the primary standard in common use. And, as

Hardman and Munn have indicated, there is wide variation in how apprentices spend those 2,000 hours and what they are able to do at the completion of them.

It was also impossible to use the performance of comparison subjects at the end of 2,000 hours, since the machine time and trainee time required to administer the shop performance tests could not be made available on the schedule needed. One alternative available was to get from the foremen who supervised the comparison subjects their ratings of how well their apprentices would perform on the 14 of the shop performance tests that were taken by the experimental group during the course of their A/V shop training. The ratings were made on a four point scale from excellent (4) to unsatisfactory (1). (See Appendix G) The results of this analysis are presented below.

FOREMEN'S RATINGS OF APPRENTICE SHOP PERFORMANCE

	Comparison Group	PBAT Group
N	40	47
Average Number of Hours of Shop Training	1177	39.30
Range	338-2300	29-57
Mean Rating of Quality of Work	3.1	3.8
Dm	.7	
t	3.88	
p	.01	

Despite the great difference in number of hours of shop training, the performance of the PBAT group was judged by foremen to be of better quality than that of comparison subjects who had thirty times the amount of shop training.

There are probably a couple of factors that help to explain these results. First, the PBAT group received intensive and systematic training -- using the A/V shop training programs -- in the performance of all the basic machining tasks on all four of the basic machine tools: mills, lathe, drills and surface grinder. The comparison subjects received their training on these machines through the conventional method of being given shop assignments haphazardly as they came through the shop. Unless training assignments are scheduled in such a way that what an apprentice is doing today reinforces what he partially learned yesterday, or if too much time elapses between similar assignments, reinforcement is lost and the result is inefficient training and poor performance. This is what research has indicated happens in many conventional apprentice training programs. The use of the PBAT shop training modules mitigated this problem to a great extent through carefully designed sequences of machine training that produce optimum reinforcement -- provided, of course, they are used properly.

Second, the 39-1/2 hours of shop training received by the PBAT group probably represents what Hardman and Munn

called "learning time". The 1,176 hours of shop training received by the comparison subjects is probably comparable to what they called "exposure time". Our results tend to support their conclusions. It appears that further exposure, beyond the time required to learn, leads to little further learning when the same or similar tasks are being performed. This point is valid of course only when the initial learning time is used efficiently.

Additional exposure beyond that required to learn may lead to further performance development, however, if the initial learning time has not been efficiently used. This can be seen by comparing the work quality ratings of comparison subjects with different exposure times. The average rating of comparison subjects with less than 1,300 hours on course was 2.9, while that of subjects with more than 1,300 hours was 3.4. Although this difference is not significant, it is in the right direction and may indicate that some learning -- albeit very inefficient -- continues to take place with concontinued exposure.

The fact that different foremen rated different trainees in different companies raises the spectre of unreliability of criterion ratings. It was not possible to obtain reliability estimates on these ratings since different journeymen supervised different phases of the apprentices' training.

Another attempt to evaluate the performance of the

PBAT group involved the time to complete the Shop Work Assignments completed by trainees in this group immediately following the completion of their A/V training sequences. (See Appendix F) In order to establish an estimated standard of performance of 2,000 hour apprentices based on actual work assignments, foremen were asked to estimate how long it would take an average 2,000 hour apprentice to complete each of nine work assignments on milling machines and lathes and to rate the quality of expected performance. These assignments were among those actually performed by PBAT group trainees after an average of 39-1/2 hours of training. Thus we had actual times and quality ratings on the experimental PBAT group. We also had estimates -- gathered from another group of foremen -- on how long it would take a competent journeyman to complete each assignment. The results of this analysis are as follows:

ESTIMATED AND ACTUAL MEAN TIMES
TO COMPLETE SHOP ASSIGNMENTS

	Estimate - 2000 Hour Apprentices	Estimate - Competent Journeyman	Actual PBAT Group
Total Hours to Complete 9 Assignments	86	52	119
Mean Hours per Assignment	9.5	5.8	13.2
Mean Differences	3.7	3.7	

Thus, after 40 hours of training the PBAT group completed these nine assignments in 119 hours. The foremen estimated that an average 2,000 hour apprentice would take 86 hours to complete them -- 28 percent less than the PBAT group. The additional hours of shop training leads to only a 28 percent improvement in estimated performance time. The question must be raised whether a 28 percent improvement could not be achieved in significantly fewer training hours through more systematic shop training procedures. The critical distinction again is that between "learning time" and simply "exposure time".

These results are also consistent with those that emerged from the TMI study of 1967. The number of hours estimated by journeymen and foremen to be required for apprentices to achieve mastery of the four basic machine tools was more than 50 percent less than that recommended by established apprenticeship time standards.

One of the more interesting pieces of anecdotal data to emerge from the present study was the fact that in one of the organizations in which comparison data were collected, foremen indicated that three of the nine Shop Work Assignments they were asked to rate -- and which our PBAT group members had actually performed successfully -- were of such difficulty that they would never be assigned to first year apprentices.

In view of our objective to lift some of the burden of

shop instruction from the shoulders of journeymen, one important result involves the amount of shop instructor time required by the PBAT audio-visual shop training programs. Shop instructors spent an average of only three hours per trainee in taking apprentices through their average 39-1/2 hours of basic machine tool training. This is in striking contrast to the amount of journeyman time normally thought to be required in conventional apprentice training programs. Unfortunately, no one that we know of has ever recorded the exact amount of journeyman time required to train apprentices in conventional programs. Thus, no direct comparison can be made. Since the amount of journeyman time required has been reported as a major problem in every study of apprenticeship, it seems likely that it is far greater than that required in the program reported here or in any program in which systematic self-instructional methods are used.

No significant relationships were found between reading or arithmetic grade levels or score on the XAP (Civil Service) test and shop performance. Correlations ranged from -.05 (XAP) to .37 (Reading Grade) but none were statistically significant.

ATTITUDES OF TRAINEES AND ADMINISTRATORS

Upon completion of the experimental PBAT program, attitude questionnaires were completed by both trainees and administrators. (See Appendix H) The data gathered are summarized below.

Seventy percent of the trainees liked using the self-instructional materials as well as or better than the conventional classroom methods found in most apprentice programs. Seventy-eight percent felt they were more effective than classroom instruction and half said they would like other courses using this method.

All of the trainees liked the self-pacing method and thought it more effective than group paced methods of instruction. Other reasons for liking this approach were: (1) the materials were performance oriented and required trainees to do rather than read about job tasks, (2) because of this fact and the reinforcement built into the programs, they felt they learned better and faster, (3) about half indicated that they had a better idea of how they were doing as they progressed through the course.

The major reason given by the 30 percent who liked the method less than regular classroom instruction was that they could learn better by listening to an instructor and some found four hours a day of self-instructional materials too intensive a schedule.

Sixty-eight percent of the trainees liked the A/V shop training method as well or better and 76 percent found it more effective than the usual demonstration method of teaching machine operation. Sixty-nine percent felt they could handle the A/V training with minimal help from an instructor.

The major criticism of the A/V materials was that the machines pictured on the 35 mm slides were not identical to the machine at which the trainee was working. This is a constant problem because of the wide variety of machines used in industry. Ideally the photos should be taken of the specific machines used in each plant.

Perhaps the best way to summarize the attitudes of the administrators toward the PBAT program is to reproduce representative responses to the questionnaire. The comments in parentheses are editorial notes inserted to clarify responses.

1. In your own words briefly compare the efficiency and effectiveness of the experimental program with more conventional first year apprentice training programs on each of the following points:

   A. The extent to which the printed programed material covered the related instruction subject matter essential for trainees to be able to perform their first year tasks on the shop floor.

      Programed instruction parts were especially better and more direct to the apprentice's work.

      Seemed to have covered the necessary material fairly well, but with some areas that were not applicable: Vises, H.S.S. mill cutters, sharpening tools, etc. (Apprentices in this company do not need to know these things.)

      Related instruction subject matter covered too extensively in printed material. Math. in particular for this level of trainee. (Algebra, geometry and trigonometry were not taught in first year in this organization.)

Was not all related to our way of doing things. Material would have to be tailor-made to our operation.

B. The learning effectiveness of the programed, related instructional materials compared to conventional classroom instruction.

The pre and post-tests were particularly helpful. Liberal use of drawings, sketches and pictures helped considerably.

The programed material seems to be at least equal to conventional instruction or possibly exceeding in effectiveness.

I found little difference in effectiveness of the two methods. Instructor spends about same amount of time administering each.

Dependent upon the individual's ability to read and retain.

C. The trainee time required to complete both related instruction and the A/V shop instruction using the self-pacing materials compared to conventional apprentice instruction.

Faster with the self-pacing materials.

As near as I can tell the times are comparable.

The D.S.C. program seems to be a time saver.

It took less time, but that doesn't mean it's better, in my opinion.

D. The instructor time required by the experimental program (both related instruction and A/V shop instruction) versus that required by conventional training programs.

1. Minimal class instructor time.
2. More time spent in administering the program.
3. Uncertain about A/V shop instruction.

About the same instructor time is required, however, in related instruction area the instructors presence is needed 100% of time but only used 20% of time, freeing instructor to do other paper work.

The D.S.C. program is a definite advantage for instructor, requiring much less time to cover equal material.

E. The effectiveness of the A/V shop instruction programs compared to the traditional instructor demonstration or one-on-one training on machine tools.

Better with A/V shop instruction because of attention by the instructor to:
1) A/V
2) Actual performance

The A/V seems to be more effective.

Traditional one on one instructor demonstration more effective.

F. The comparative value of the self-paced approach compared to traditional group pacing instructional methods in apprentice training.

We have used a self-paced approach prior to this new program.

It is of great value because there is a challenge for even the brightest and/or fastest of trainees.

2. What do you feel are the major advantages and disadvantages of the experimental, individualized program compared to the more traditional approach?

Advantages:

Self-paced.
Related subjects blended to doing many parts on the floor.
Objectives more clearly defined.

1) Work at own individual rate.
2) Achievement level approximately equal for all students.
3) Even though instructor must be present all the time, he has free time to do other paper work. (Classroom only.)

Clear A/V.
Repeat instruction controlled by trainee.

Disadvantages:

Administration of program takes considerably more time initially.

Time limits are ignored, where in actual on-the-job experience it is of importance.

Limited machine tools in slides. Leaves time to trainee as far as set-ups are concerned.

3. Based on the results of this experimental program, do you believe it should be possible to accelerate apprentice training through the use of such individualized instructional techniques?

Yes.

Not really; I feel the times are comparable.

Yes.

4. Please make additional comments on what you see as the implications of this type of program for apprentice training or for other types of technical training.

Useful for OTJ non-indentured programs and possibly new employee orientation programs.

I think this method has promise, but it must be matched to the machine you're training on and the related material must agree with the methods and techniques used by the trainee.

5. Please comment on whether you think such a self-paced program would be an effective way of helping a greater

number of educationally disadvantaged youth to get into and successfully complete apprenticeship or skilled trades training programs.

It should.

No, I feel the educationally disadvantaged have a reading inefficiency and would not be able to comprehend and then apply what they supposedly learned.

I think the program would not be an effective way of helping a greater number of youths. Maybe better trained.

In my opinion this type of program would not help a greater number of educationally disadvantaged youth, because the individual must be able to read with understanding and follow instructions and retain the information.

6. Please comment on the extent to which trainees, when they completed the experimental program, were better or less well prepared to perform on the shop floor than trainees who have been in a conventional training program for a comparable period of time.

Because a greater mass of information was given in a concentrated, shorter period of time, orientation to shop work was accomplished sooner.

The experimental students seemed to have more confidence in themselves. However, they generally are experienced (trained) on a different manufacture name machine. (Machines on slides were different from the ones on the floor.)

In three weeks period of time a conventional trainee has worked on only one machine. The trainee in the experimental program worked on four machines during the same period of time. In my opinion they have gained considerably in the area of self-confidence.

In general, both trainees and administrators were

positively disposed toward the PBAT program. Not all trainees were able to use the self-instructional method effectively. Some, especially those with lesser reading skills, felt more comfortable when learning by listening. They all liked the idea of being able to control their own learning pace, and most favored the use of this method for advanced apprentice courses.

Administrators, although their attitudes were positive, were not convinced that the program could be used with the disadvantaged, although most of them did believe that it could accelerate apprentice training. In fairness to these instructors and administrators it should be pointed out that, at the time they completed the questionnaires they had no knowledge of the fact that seventh and eighth grade readers -- (and some sixth grade readers, with careful administration) -- are capable of completing the program successfully. Nor were they aware of the final figures on the savings in both training and instructor time. Their attitudes reflect in part the reticence in the face of change that is a normal and unremitting part of every-day industrial life.

One eloquent comment on the effectiveness of the program is the decision on the part of one of the participating companies to adopt the methodology of the PBAT program for most of their future training programs. Their internal training personnel have been trained in the new educational techno-

logy, they have budgeted for audio/visual equipment and the staff is currently developing programs for training both experienced and newly hired personnel in complex skills involving sophisticated machinery.

IMPLICATIONS OF THE STUDY

The results of the study suggest a number of considerations which have implications for manpower policy.

1. Perhaps the most important of these is that several studies, including this one, have demonstrated that the most critical variable responsible for producing competent skilled tradesmen (either first year apprentices or journeymen) is not the number of hours spent in training; it is clearly and unequivocally the quality, intensity, effectiveness and sequencing of the training experiences that the apprentice goes through during each hour of his training that leads to successful performance development. This is the aspect of apprentice training that is now under poorest control and where the greatest inefficiencies exist. Clearly, it is the area in which future work should be concentrated.

   If employers, unions and the relevant government agencies are genuinely interested in performance development and in modernizing apprentice training, rather than having apprentices serve time, manpower policy must seriously consider the promulgation of apprentice and journeyman standards under which measured performance is the primary criterion of both movement through train-

ing and the attainment of journeyman status. Time should be allowed to vary or used as a secondary criterion. The precedent has already been set by the labor agreement between the UAW and Ford Motor Company and by the concept of the Personal Achievement Record of the Ontario Department of Labour. Under no circumstances can we recommend that new diminished time standards be established. Training time should be variable, not fixed, and subordinated to measured performance.

2. A major contribution could be made by the U.S. Department of Labor to the achievement of such a modern, efficient and flexible apprentice program if the Office of Research and Development and the Bureau of Apprenticeship and Training were to cooperate in the development and implementation of such a performance oriented policy.

   Implementation could be achieved most effectively by converting the current BAT apprentice standards to specific measurable performance objectives stated in specific behavioral terms. These should be based on up-to-date empirical job analysis. Once such objectives have been developed, a long range program -- probably through the BAT -- should be developed to help industry implement them.

3. The suggestions above require the development and standardization of reliable and valid performance tests. The use of such tests would provide more objective

evaluation of the skill development of trainees and of the effectiveness of training programs and would be consistent with the provisions of the Civil Rights Act.

Many private industrial firms, in response to the Civil Rights Act, are struggling with the problem of how to evaluate performance objectively and in compliance with the Act. The U.S. government could aid materially in this effort -- and also accelerate equitable enforcement of the provisions of the Civil Rights Act -- by a systematic effort to create a receptive climate in industry, to disseminate information on the performance or behavioral systems approach to training and develop the procedures necessary to implement such an approach on a nationwide basis. Such implementation cannot take place, except in isolated experimental instances, until manpower policy faces the problem squarely.

4. The role of selection versus training administration in producing competent journeymen should be explored through much more systematic research.
5. It would be most useful if the government could encourage -- through dissemination of information or other means -- the development of training materials that are prepared for reading skills at the seventh to eighth grade levels. The military has found this to be a problem, and it is one which exists also in industry.
6. Our own research and review of the pertinent literature

reveals that many people who are responsible for apprentice training lack even elementary knowledge of the new educational technology and of the newer instructional methods. An effort to rectify this serious gap in knowledge would do much toward loosening the tradition-bound rigidity that most investigators have found in apprentice programs. A series of regional conferences or some such devices might help. More effective in the long run, however, might be a set of criteria of the successful apprentice instructor and administrator that included knowledge and application of current educational methodology.

7. Finally, all of the above could be accomplished -- and on an accelerated schedule -- with the establishment of an ongoing technical training research and development program -- perhaps housed in regional demonstration centers -- out of which could come empirically derived answers to the many problems faced by apprenticeship today. One of the most critical of these issues is the question of generality of training versus specialized training, and what combination best fits the needs of modern industry. Such a problem could address a host of the other problems revealed by this and other studies.

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APPENDIX A

DESCRIPTIONS OF EFFECTIVE TRAINING PROGRAMS

Ford Motor Company
Ontario Department of Labour
Waubonsee College

FORD MOTOR COMPANY PROGRAM

The new Ford apprentice training programs are firmly grounded in a modern task analysis. A task analysis of nine basic trades was conducted several years ago by outside consultants and required approximately 18 months to complete.

Probably the most extensive and detailed task analysis of the skilled trades ever conducted by American industry, the study included 2500 apprentices, journeymen, engineers, foremen and management personnel in 22 plants across the country.

The study was designed to provide empirical data on all the tasks performed by journeymen in each trade, frequency and criticalness of each task, measurable standards of acceptable performance, the cognitive and perceptual skills required to perform each task, how and from whom each task was learned and the nature of the learning tasks or processes involved in learning to perform each task.

All of these data were fed into computers and the outputs were analyzed. They provided, for the first time, systematic documentation of the performance and training requirements of each trade. The rational, armchair approach to training curriculum development was no longer needed. The new training system could be designed based upon the clear reality of what was required on the shop floor.

The analysis revealed that all of the same problems

existed in the Ford programs that have been identified in studies of apprentice training in other organizations. Apprentices -- particularly during their first year -- were frequently found to be helpers or production workers rather than trainees. They usually came on the shop floor inadequately prepared to perform the tasks of the trade. Apprentices in the metal trades spent 44 percent of their time during the first year learning to operate machine tools that -- once they became journeymen -- would consume less than five percent of their time. While the basic skills of the trade were relatively easy to learn, applying these skills to different types of equipment on the floor was considerably more difficult. Eighty-five percent of the apprentices' training was received from journeymen most of whom had never received training on the techniques of training others or who had little time available to act as instructors. A good deal of specialization occurred among both journeymen and apprentices. Only a small number of the former could, or had the opportunity, to perform all the tasks of their trade. Because of the single time requirement, individual differences in learning ability were being ignored causing frustration among apprentices. Related training was often out of phase with shop training and some courses being taken were largely irrelevant to the requirements of the job. Both shop and related instruction were in need of up-dating with respect to instructional methodology. Job rotation and sequencing were at times haphazard and often unrelated to

training requirements.

Evaluation of these problems led to the development of a set of objectives for the new training system:

1. The practical definition of apprentice needed to change from helper to trainee.
2. Training needed to be sequenced so that production tasks were not assigned to apprentices before they had acquired at least the minimal skills required to perform them.
3. Apprentice progress through the program should be based on measured task achievement rather than number of hours spent.
4. Better design, integration and phasing needed to be achieved between shop and related training.
5. Better methods were needed to make more efficient use of journeymen as trainers.
6. Instructional techniques needed updating to take advantage of new training technology and the application of basic learning principles.
7. Since the task structure of each trade was clearly specified, it was possible to develop a truly individualized training program. This provided the opportunity to broaden the base of apprentice applicants.
8. Placement of an apprentice on the program should be based on his level of knowledge and skill.

To achieve these objectives a totally new program was designed that involved the following elements: (1) complete revalidation of apprentice selection measures, (2) a new pre-apprentice program which enables certain applicants to upgrade their skills and qualify for the waiting list, (3) a new vestibule Basic Shop Training Program for the metal trades that is modular in design, self-paced and performance rather than time oriented, (4) the development of behavioral objectives which are being used to develop a modular related training system that is job performance rather than curriculum oriented. It will, when completed, consist of a core curriculum plus a large number of elective modules and it too, will be task-achievement rather than time oriented.

There is no minimum education requirement for admission to the new program. The apprentice applicant takes a battery of tests that includes measures of verbal, numerical and mechanical skills and space visualization. Minimum test scores have been established for each of three trade groups -- electrical, metal, and maintenance. The successful applicant is placed on the waiting list for the trade group of his choice for which his scores qualify him. Candidates are placed on the program from the waiting list in chronological order.

If he is a Ford employee and fails any of the entrance tests, he may enter the Pre-Apprentice Training Program -- a program that may help increase the number of minority group

members who enter the skilled trades. He is given diagnostic tests to determine his specific deficiencies. Once these are determined, an individual learning plan is worked out for him with the help of a counselor.

Under the tutelage of retired Ford journeymen, working in the local school system and using commercially available programed self-instructional materials, he then completes instructional modules in those areas in which his skills are deficient. Once these deficiencies have been remedied the instructor certifies successful completion of pre-apprenticeship and the employee qualifies for the waiting list without having to retest. Initial results from the program indicated, however, that on the second time through, some applicants were able to raise their scores on the entrance tests by as much as 100% after 20 hours of instruction.

Once on the program, the new apprentice starts using one of the new Training Guides for his trade that are arranged not by subject but by task. The guide contains every task he is required to learn during this basic training program. Further, it contains the information he needs to learn how to perform the task, together with the performance requirements he must meet before he can move on to the next task.

No specific time is set for the learning and performance of each task. When the apprentice feels he is ready, he asks the instructor to give him the performance test. If his

performance is satisfactory, he is signed off by the instructor and he is ready to go on to the next task. If his performance is not satisfactory, the instructor provides the help he needs and he continues to work on the same task until he does meet specifications.

The modular Training Guides combine the skill and knowledge of the journeyman with modern self-instructional, task-oriented methodology. They have the advantages of: (1) providing uniform training to all apprentices, (2) reducing the amount of journeyman time required for training on the shop floor, (3) more efficiently utilizing the time of apprentices, shop instructors and journeymen, (4) providing more systematic and objective measures of apprentice competence, (5) insuring that new apprentices when they first move onto the shop floor are capable of carrying their own weight and, (6) systematizing rotation of apprentices through shop training so that each is exposed to all the tasks of his trade and none gets stuck on a single phase of training either because he happens to be good at it or for reasons of production requirements.

The initial results of the new program indicate that new apprentices can, in an average of 480 hours, achieve the same level of shop competence that was achieved in 12 months of training under the old apprentice program.

From Basic Training, apprentices move on to advanced

training covering what is normally taught during the second, third and fourth years of training. Similar self-instructional Training Guides are used for advanced shop training and with comparable results.

In related instruction a complete set of behavioral objectives have been developed based upon the original task analyses. These objectives are task oriented and are to be used to establish the content of related instruction courses.

The end product of this approach is the establishment of a modular core curriculum in both shop and related instruction that is self-pacing and firmly rooted in task performance. Once the core curriculum has been mastered, apprentices move on to advanced training and ultimately to elective courses which may be applied to a long-range career development program.

The Ford apprentice training program is administered jointly by the company and the union. The basic 8,000 hour total which includes 576 hours of related instruction have not been eliminated. But, since the core curriculum of related instruction may require no more than an average of less than 300 hours, the program provides much greater flexibility than did the older programs. Related instruction modules, hopefully, may be taken in a variety of different sequences depending on what is needed to complement what the apprentices are doing in shop training or on the floor.

The program, so far, has drastically cut the average number of hours of shop training required to reach levels of job performance comparable to those achieved under the old program. The entire program is now geared to a criterion of job performance rather than courses taken or hours on course. And, it is the only program that we know of in which the labor-management agreement calls for movement through the apprentice program based on task achievement -- as outlined in the Training Guides -- and which uses hours on course only as an outside limit. It may well be the most up-to-date and effective apprentice program in the U.S.

CANADIAN MODULAR BLOCK SYSTEM

Prompted by a number of factors, including industry's desire for a more flexible apprentice training program and the need for closer integration of industrial training and vocational education, the Industrial Training Branch of the Ontario Department of Labour began, in 1966, developing the design of a new system of apprentice training. Fortunately,

the people working on the project were possessed of an uncommon amount of common sense and, apparently, some knowledge of modern training technology. They recommended a program that would be versatile enough to:

(a) Be adaptable to technological change,

(b) Provide flexibility of occupational choice,

(c) Identify a core of training and experience that is common to more than one occupation,

(d) Integrate institutional (school) and in-plant training with recognition of standards established in either locale,

(e) Recognize individual learning capabilities, with the length of training being determined on the basis of knowledge and skill achievement, and

(f) Provide accreditation on the basis of attainment of knowledge and skill performance standards.

To do justice to this program it may be best to use the very articulate description of it written by Miss Marion Dempsey of the Ontario Department of Labour and published in the Canadian Personnel and Industrial Relations Journal.[7] The following description is excerpted from that article:

> The development of a block system begins with an analysis of the work functions of a family of homogeneous occupations in a particular industrial environment. This analysis of work activities is known as a functional analysis of the occupational area. The analysis is conducted by on-site observation of worker activities and personal interviews with supervisors and workers. This information which identifies the functional demands of the work area permits the identification of the elements

of skills and knowledge required to perform these functions.

The elements of skill and knowledge so identified are assembled into blocks. The blocks, in turn, are arranged in the form of a grid or matrix which forms the basis of the training program and provides at the same time a graphic illustration of all the knowledge and skill components contained in the given occupational area.

Of these blocks a significant number will be found to be common to all the occupations in this area and can be grouped together to form a common core. It is now possible to establish skill or occupational profiles by selection of the pertinent blocks.

For each block, a training package is developed by the Industrial Training Branch, in co-operation with representatives of the industry involved. Each training package consists of a statement of specific course objectives, a curriculum outline, a list of suggested reference texts and learning aids, performance standards, and a terminal test.

Some curriculum blocks will be largely academic representing trade theory and skills which can best be taught in a classroom environment. Such training is carried out in the nearest available educational facility usually the local College of Applied Arts and Technology or in-company.

The remaining curriculum blocks will represent training of a practical nature which can best be provided on-the-job under normal working conditions and under the instruction of company personnel trained in instructional techniques.

Because there is no academic prerequisite to the Block Training System, it is considered essential that a form of pretesting be carried out. Pre-testing determines the entrance level of the trainee, so he avoids taking training in blocks in which he may be already competent.

Completion of a specific block is reached when the trainee, in the judgement of his instructor, has reached an acceptable level of competence in that block and is ready for testing under the supervision of the Industrial Training Branch. Attainment of the prescribed performance standards signifies that the trainee has reached the desired level of competence in a particular block and is now entitled to formal recognition of his achievement.

The Block Training System does not change the worker's duties but describes his job in detail and provides a systematic approach to training in the elements that combine to make up that job.

This system provides unlimited flexibility in that the worker may extend his training as dictated by job requirements or personal ambitions while receiving accreditation for attaining performance standards.

From an examination of the Block System of Training it will be evident that this system will offer a number of distinct advantages for both the worker and his employer.

FOR THE WORKER

Formal recognition for attainment of skills, knowledge and competence.

Flexibility of occupational choice.

Portability of skills through establishment of an accredited skill profile.

Incentive towards self-improvement.

A reduction in overall training times.

Provision for proceeding at a rate consistent with individual learning capabilities.

FOR THE EMPLOYER

Clearly defined training objectives to facilitate the training of the worker for a specific need.

General use of skill profiles in industry will provide a valuable aid in employee recruitment and selection.

Training time reduced, thereby producing skilled workers more quickly.

A means whereby incentives may be provided to encourage self-improvement in the worker.

Pilot Project

Feasibility studies have been conducted in the following industries: welding, furniture, electrical appliance manufacturing, soap and detergent, textiles, chemical and food processing.

In addition, a number of traditional construction trades such as carpentry, air conditioning and refrigeration have been examined to determine the feasibility of applying a block training system to them. Pilot projects have been conducted in the tooling and textiles industries.

As a result of the feasibility studies, and pilot projects, the concept has been seen to be equally applicable to the factory crafts in the whole manufacturing sector of the economy.

One of the most recent pilot projects was conducted at Polymer Corporation, a crown-owned, multi-million dollar corporation employing over 3,000 workers. It is the only company in Canada making synthetic rubbers in dry and latex forms.

Two Standards Officers from the Industrial Training Branch made a functional analysis of the family of occupations consisting of boilermakers, carpenters, electricians, insulators, industrial mechanics, painters, pipefitters, machinists, riggers, welders, sheetmetal workers, instrumentation mechanics, air conditioning and refrigeration mechanics.

Once the analysis was complete, sample blocks of training were assembled. A training block contained the objective, training content, suggested training aids and guides, training detail, and performance standards expected. For example, an operator of a centre lathe was required to perform the following operations: cutting tapers, contours and eccentrics, and internal grooving and screw cutting. To test the proficiency of the trainee for accreditation, workpieces machined had to include:

1. Taper turning dimension to be within tolerance of .001 inch.

2. Internal grooving, and eccentric turning to be within a tolerance of .001 inch.

3. Surface finish of 125 microinches R.M.S. or better. All operations would not normally occur on one workpiece; therefore, trainees required experience on several workpieces to ensure coverage. Operations included eccentric turning, knurling, internal grooving, turning external tapers and external thread-cutting.

The Standards Officer drew up a matrix of all the blocks

of training, then consulted their occupational analysis, and selected blocks of training from the matrix to make a skill profile for each of the worker classifications. The eight common core blocks were basic mathematics, blueprint, measurement, drafting and sketching, physics, benchwork and rigging.

The next step was to co-ordinate facilities for classroom training at the Lambton College of Applied Arts and Technology. The college was to supply textbooks and follow the blocks of training set out by the Industrial Training Branch.

Polymer Corporation selected the 17 trainees from over 300 applicants. Selection was based on results of aptitude test batteries, seniority and qualifications.

The training was to start in four trade classification areas where it was most needed: boilermakers, industrial mechanics, pipefitters and insulators. The Industrial Training Branch then administered pre-tests for each one of the common core blocks. With the exception of one trainee, all the men needed training in more than half the subjects; three men needed training in all subjects.

The common core subjects were covered in ten weeks. The trainees had day release for two full days a week so they were spending three days working at the plant and two days studying at the college. Polymer paid the trainees' wages while they were at the college.

Training on the job was done by Polymer personnel. Lambton College provided the instructing tradesmen and supervisory personnel with a course on instructional techniques before on-the-job training commenced.

From the description above it is clear that this carefully designed system meets most of the criteria of a modern training system: (1) It is built upon the firm foundation of an up-to-date empirical occupational analysis, (2) performance rather than time is its primary criterion of achievement, (3) it is self-pacing and utilizes rather than ignores individual differences in learning ability, (4) its modular approach attempts to minimize the temporal discontinuity

usually found between school and shop instruction, (5) it minimizes training time, (6) instruction is based on clearly defined and empirically derived behavioral objectives and, (7) shop instructors were given training in how to train others.

There is another unique feature of this program that American industry might do well to consider. This is the Master Training and Accreditation Matrix which identifies the training blocks required for training in a given occupation. The Personal Achievement Record (shown on the next page) which the employee takes with him from job-to-job and which is an objective record of the training blocks in which he has attained mastery. With such an objective achievement record employers no longer need rely on the vague criterion of hours of training or years of experience to judge whether or not an applicant is competent or in what areas his competence lies.

The acid test of any training system, no matter how well developed, is how well it functions in practice. The Canadian program has been tested in a wide variety of companies in diverse industries. A library of nearly 500 different training blocks has been accumulated. The reaction to the new system by both educators and industrial people has been reported to be uniformly excellent. If the system continues to develop as it has so far, it may well be one of the outstanding programs we have encountered. This would be especially

The Personal Achievement Record

ASTER TRAINING AND ACCREDITATION MATRIX

LOCK IDENT.	BLOCK TITLE	BLOCK IDENT.	BLOCK TITLE
32	Read Out & Display Systems	169	Layout - machinist
186	Pneumatic Controllers	175	Safety
43	Telemetry	163	Measurement Precision Instruments
120	Fundamentals of Instrumentation		
98	Measurement - temperature		
87	Measurement - pressure		
65	Flow Measurement		
76	Level Measurement		
54	Test & Calibration		

PERSONAL ACHIEVEMENT RECORD

INDUSTRIAL TRAINING PROGRAM

BLOCK IDENT	BLOCK TITLE	BLOCK IDENT.	BLOCK TITL
32	Read Out and Display Systems		
186	Pneumatic Controllers		
43	Telemetry		
120	Fundamentals of Instrumentation		
98	Measurement - temperature		
87	Measurement - pressure		
65	Flow Measurement		
76	Level Measurement		
144	Math. Algebra & Trig.		
155	Maths, Square roots		
166	Mathematics - arithmetic		
167	Physics - work		
156	Physics - instrument		
168	Blueprint Basic		
176	Basic Electricity		

804.137.408

(NAME) L. A. ROWAL (SOCIAL INSURANCE N

(ADDRESS) 285 Rushmore Drive,

Cornwall, Ontario.

PERSONAL ACHIEVEMENT RECORD (continued)

BLOCK IDENT.	BLOCK TITLE

ISSUED BY INDUSTRIAL TRAINING BRANCH, ONTARIO DEPARTMENT OF LABOUR, 74 VICTORIA STREET, TORONTO 210, (

true if more self-instructional technology is built into future versions of the system to more fully implement the self-pacing aspect of it and to reduce the instructor time.

WAUBONSEE COMMUNITY COLLEGE

There is a growing number of community and technical colleges and some secondary schools that are travelling what is becoming the well-worn path toward performance oriented, self-instructional curriculum programs based upon detailed behavioral objectives. Stimulated by the work of the Armed Forces and by the newer training methodology used in many industries, so many are going in this direction that it would be impossible to list or describe here all the programs that now exist or are in development. We have chosen a program to describe as the prototype of many of those that are now being developed.

Waubonsee Community College in Sugar Grove, Illinois has, during the past year, individualized instruction in automotive technology and machine shop practice and theory. Under the direction of Mr. Ken Ronzheimer, and with the dedicated involvement of his technology faculty, full year courses have been developed in automotive engine design and operation, automotive electricity and machine shop practice.

Following is the outline for the 18 unit course on

automotive engine design and operation:

UNIT AND ASSIGNMENT SHEET
AT 151 AUTOMOTIVE ENGINE DESIGN AND OPERATION

UNIT 1: SHOP LAYOUT
- Assignment A: Introduction to the engineering technology facilities
- Assignment B: Introduction to the automotive technology facilities
- Assignment C: Introduction to engine lab

UNIT 2: SHOP SAFETY AND PRACTICES
- Assignment A: General rules and regulations (technology)
- Assignment B: Shop safety
- Assignment C: Auto shop rules and regulations

UNIT 3: HAND TOOLS
- Assignment A: Basic mechanics hand tools
- Assignment B: Special automotive hand tools
- Assignment C: Torque and torque wrenches
- Assignment D: Tool control system

UNIT 4: MEASURING TOOLS
- Assignment A: Types of precision measuring tools
- Assignment B: Reading, use, and care of micrometers and other measuring tools

UNIT 5: FASTENERS
- Assignment A: Bolts, nuts, and machine screws
- Assignment B: Locking devices
- Assignment C: Rivets and riveting

UNIT 6: TUBING, FITTINGS AND HOSE
- Assignment A: Copper, steel, and plastic tubing and fittings
- Assignment B: Cutting, flaring, and bending tubing
- Assignment C: Hoses and hose fittings

UNIT 7: GASKETS, SEALS AND SEALANTS
- Assignment A: Gasket materials, construction, and installation
- Assignment B: Gasket making
- Assignment C: Seal materials, construction, installation and removal
- Assignment D: Sealants

UNIT 8: ENGINE FUNDAMENTALS
- Assignment A: Basic 4-stroke cycle gasoline engine design and operation
- Assignment B: Automotive engine design and operation

UNIT 9: ENGINE COMPONENT DESIGN, CONSTRUCTION AND IDENTIFICATION
- Assignment A: Engine component design and construction
- Assignment B: Engine part identification

UNIT 10: ENGINE CLASSIFICATION
- Assignment A: Methods and criteria for classifying engines
- Assignment B: Identification of different engines

UNIT 11: VALVE TRAIN INSPECTION AND SERVICE
- Assignment A: Cylinder head removal and replacement
- Assignment B: Rocker arm, push rod, and lifter inspection and service
- Assignment C: Valve removal, inspection, and measurement
- Assignment D: Valve guide and seat inspection and measurement
- Assignment E: Valve spring inspection and testing
- Assignment F: Cylinder head reassembly

UNIT 12: CAMSHAFT AND TIMING GEAR INSPECTION AND SERVICE
- Assignment A: Timing chain and gear inspection and removal
- Assignment B: Camshaft removal, inspection and measurement
- Assignment C: Camshaft bearing inspection and installation
- Assignment D: Camshaft and timing gear installation and valve timing
- Assignment E: Valve adjustment

UNIT 13: PISTON AND ROD ASSEMBLY INSPECTION AND SERVICE
- Assignment A: Piston assembly removal and replacement
- Assignment B: Piston and ring assembly inspection and measurement
- Assignment C: Rod alignment

UNIT 14: CRANKSHAFT AND FLYWHEEL INSPECTION AND SERVICE
- Assignment A: Crankshaft removal, installation and clearance measurements
- Assignment B: Crankshaft inspection and measurement
- Assignment C: Flywheel inspection, removal and replacement

UNIT 15: ENGINE BLOCK INSPECTION AND SERVICE
- Assignment A: Cylinder inspection and measurement
- Assignment B: Block inspection

UNIT 16: ENGINE LUBRICATION SYSTEMS
- Assignment A: Automotive engine lubrication system design and operation

Assignment B: Oil pump inspection
Assignment C: Oil passages and filtration system inspection

UNIT 17: ENGINE COOLING SYSTEMS
Assignment A: Automotive enginer cooling system design and operation
Assignment B: Cooling system and water pump inspection
Assignment C: Thermostat inspection and testing
Assignment D: Cooling system testing

UNIT 18: ENGINE TESTS AND MEASUREMENTS
Assignment A: Horsepower and torque measurement
Assignment B: Determining engine size and compression ratio
Assignment C: Dynamometer testing
Assignment D: Engine dynamometer operation

The automotive lab has been equipped with a number of home-built study carrels each containing a rear screen sound-slide projector. Additional portable projectors are mounted on castered cabinets so they can be used at the engine being worked on, or at the automobile in the auto shop. These portable units are also used alongside the lathes, milling machines and other power tools in the machine shop.

A large number of individualized step-by-step sound-slide programs have been developed by the faculty based on carefully worked out behavioral objectives. Information sheets developed by the staff, commercially available textbooks, assignment sheets, worksheets and self-tests are also used as instructional materials. A sample of the behavioral objectives covering one lathe task is set forth below.

COURSE: TE 151 - Machine Tool Lab I

UNIT: 10 - Engine Lathe - Operations Between Centers

ASSIGNMENT: A - Straight Turning to a Shoulder

OBJECTIVES:

1. Given a 3/4" diameter x 8" long C.R.S. workpiece that has been center drilled, you will be able to turn that workpiece to three specific diameters with square shoulders where the diameters meet each other.

2. Given your center-drilled workpiece, you will be able to turn three specific diameters to the lengths stated on your DPV54 print packet, part four (4).

3. When you're given a description of a shoulder turning situation, you will be able to choose correct steps of procedure used to produce the square shoulder.

4. You will be able to explain in writing how the tool bit is positioned for turning a square shoulder to a layout line.

5. Given a length measurement situation on a workpiece held between centers, you will be able to choose the correct method for accurate length measurement.

6. You will be able to explain in writing the two (2) steps used to properly set the pressure on the centers for turning between centers.

7. You will be able to choose the correct reason for using a lathe dog for turning between centers.

8. Given a specific diameter, you will be able to calculate (using arithmetic) the amount left to be turned after the first rough cut is finished.

9. When given the term "shoulder", you will be able to choose reasons for turning a square shoulder and also reasons for turning a shoulder with a radius at its base.

OBJECTIVES: (cont.)

10. You will be able to write the correct procedure for setting a zero point on the lathe's crossfeed micrometer dial.

11. You will also be able to choose the best reason for setting a zero point before adjusting the crossfeed to a depth of cut.

12. When given the term "lathe center", you will be able to choose correct statements concerning the construction and use of live and solid centers.

13. You will be able to choose correct solutions when given problems commonly occuring when live centers are used.

PROCEDURES:

1. Read pages 188 - 195 in your text.

2. Read and study the attached information sheet.

3. View the sound-slide series 10A and do the operations described there.

4. Ask your instructor to inspect your results.

5. Completely clean your lathe and put your tools away in their proper places.

6. Have your instructor check out your cleanup job.

7. Complete the attached self-test.

8. Grade your self-test with the answer book provided.

9. See your instructor for his evaluation of the written portion of the self-test.

ADDITIONAL REFERENCES:

1. Sound filmstrip "The Lathe - Setting Up Work"

2. Machine Tool Technology - McCarthy, pages 247 - 253

3. Modern Metalworking - Walker, pages 36 - 19 to 36 - 20.

Typically, students in these courses are on a self-paced schedule. They check into the automotive lab, for example, and check the large progress chart mounted on the wall. On this chart each student's progress is charted, the assignments he has completed, and his grade on each of the unit tests in the course. From the chart he can tell which assignment he is to work on that day, or what one he must repeat because he did not score 80 percent or better on the unit test on his first try.

He gets out his assignment sheet, checks out the appropriate A/V program and completes the assignment either in a study carrel or on the floor if he's working on an engine or an automobile. When he has completed the assignment, he asks for the unit test, completes it and turns it in for grading. His grade is then posted on the public wall chart. He continues this procedure until all units have been completed and he has taken the mid-term and final exams. In the first full-year test of the program this past summer every student scored 80 percent or better on the final exam on the first attempt.

Not only is the system producing better learning, under the old instructional system the Waubonsee staff was able to handle about 85 students. With the new program they now enroll 200 students in automotive technology, and they estimate they could handle far more than that number.

Although the development of such a course, especially

where the instructors do all the photography, record the instructions, prepare behavioral objectives, information sheets and exams, appears to involve a prohibitive amount of work, Mr. Ronzheimer has indicated that it requires no excessive amount of work over and above that needed to prepare course outlines and lecture-demonstrations. And, once the course is developed, the instructor has considerably more free time to devote to helping individual students, improving or up-dating the materials or preparing new courses.

Similar courses are in operation at Central Nebraska Technical Institute, Central Piedmont Community College and a host of other schools throughout the country. In each case the benefits far outweigh the disadvantages and the cost of setting up the program. Even the cost can be kept to a minimum by having all equipment except projectors built by students as curriculum or extra-curricular projects.

The majority of these programs, like the DSC developed apprentice training system, are solidly based in modern training technology. They are: (1) based on carefully developed behavioral objectives, (2) performance oriented, (3) base movement through the program on measured performance, (4) allow time to vary with learning rate and ability, and (5) depend on the inherent interest and motivation of the student in his own achievement rather than imposing external rewards and punishments.

As a result, they all report significantly better performance on the part of students and considerable reduction in training and instructor time.

APPENDIX B

BEHAVIORAL OBJECTIVES RELATED INSTRUCTION

No attempt has been made to include here, or in Appendix C -- Behavioral Objectives -- Shop Instruction, all of the data gathered or all of the judgments made in developing these behavioral objectives. In the interest of brevity only the behavioral statements which define major tasks have been included.

BASIC HAND TOOLS

Upon completion of this module, trainee will be given an achievement test. Trainee will be considered successful if he can perform each objective below with 100 percent accuracy.

Trainee will be able to:

1. Given several drawings, choose the one which shows the correct way to tighten a vise.
2. Tell why a vise should not be tightened with a hammer or a pipe.
3. Tell why caps are sometimes used to cover the jaws of a vise.
4. Given drawings of cross filing and draw filing, identify each.
5. Tell which type of filing is best for: (1) roughing down a surface and (2) producing a fine surface finish.
6. Given drawings of a single cut file and a double cut file, identify each.
7. Tell which cut of file is best for: (1) roughing down a surface and (2) producing a fine surface finish.
8. Given cross sectional views of 5 widely used file shapes, identify each.
9. Given several drawings, choose the one which shows the ball-peen hammer held and used correctly.
10. Tell why a handle is needed on a file.
11. Given appropriate drawings, match 5 common chisels against the type of cut each can make.
12. Tell why a chisel with a mushroom head should never be used in that condition.
13. Given appropriate drawings, choose the one which shows an adjustable wrench being used correctly and tell why.
14. Given a drawing of a set screw, a standard screw and a phillips head screw, choose the kind of tool which can be used to tighten or loosen each.
15. Given appropriate drawings, choose the one which shows the hacksaw blade correctly inserted in the frame and tell why it is correct.

16. Given a drawing of a hacksaw blade straddling a piece of work, tell: (1) what will happen to the teeth when cutting pressure is applied and (2) what rule to follow to keep this from happening.

17. Given drawings of an adjustable wrench, an open-end wrench and slip joint pliers turning a nut, choose the one which shows misuse of the tool.

18. Given appropriate drawings, choose the screwdriver blade that fits the screw properly.

19. Given appropriate drawings, choose the one which shows the hacksaw being used properly.

LINEAR MEASURE AND FRACTIONS

On completion of this modular unit, the student shall be required to achieve at least a 90 percent score on a test where he/she will be able to:

1. Add and subtract simple fractions as encountered in fractional measurements.

2. Reduce fractions to simplest form in problems as encountered in fractional measurements.

3. On diagrams of a machinist's pocket rule (fractional) read dimensions marked, to within the smallest division shown on that scale.

4. With a machinist's pocket rule, measure given line segments correct to within 1/32".

5. With a machinist's pocket rule, measure given machine parts to within 1/32".

6. With outside calipers and a machinist's rule, measure given samples of round and flat machine parts to within 1/32".

7. With inside calipers and a machinist's rule, measure the inside diameter of given machine parts to within 1/32".

8. With a slide caliper, measure both inside and dimensions of given machine parts to within 1/64".

9. With a rule depth gage, measure the depth of holes in given machine parts to within 1/32".

10. Compute missing dimensions on a blueprint type drawing.

MICROMETER INSTRUMENTS AND DECIMALS

Upon completion of this module, trainee will be given an achievement test. Trainee will be considered successful if he can perform each objective below with the accuracy specified.

Trainee will be able to:

1. Given several drawings, choose the one which shows the micrometer held correctly. (100% accuracy.)

2. Select from several alternatives the correct way that a machinist would express a dimension such as: 2.61". (100% accuracy.)

3. Add, subtract, multiply and divide decimals. (90% accuracy.)

4. Convert fractions to decimals by using a decimal equivalent table. (90% accuracy.)

5. Given a drawing of an outside micrometer, take a reading of each scale. (90% accuracy.)

6. Take a total reading from a drawing of an outside micrometer. (90% accuracy.)

7. Given a drawing of a part with dimensions and an acceptable tolerance, determine the largest and smallest size the part can be. (90% accuracy.)

8. Given both a part drawing and a drawing of a micrometer, determine whether the size of the part falls within the given tolerance. (90% accuracy.)

9. Read the setting shown on a drawing of a reverse scale micrometer (inside caliper and depth gage). (90% accuracy.)

10. Check the zero reading from both drawings and the micrometer to determine whether the micrometer is in or out of adjustment. (100% accuracy.)

11. Given drawings of the following instruments, select which precision instrument can be used to measure the dimensions indicated on given drawings of machine parts. (100% accuracy.)

    a. Outside micrometer
    b. Inside caliper micrometer

c. Depth gage micrometer
d. Inside micrometer
e. Small hole gage
f. Telescoping gage

12. Measure sample objects with a 1" outside micrometer to within .001". (90% accuracy.)

BASIC INDUSTRIAL MATH

Upon completion of this module, trainees will be able to do the following with 90% accuracy:

1. Given blueprints with incomplete dimensions in both decimal and fractional form, compute the value of the unknown diameter.

2. Solve and simplify elementary equations of the form $4a = \frac{48}{6} \times 4$.

3. Solve and simplify problems involving: ratios, proportions, speeds (RPM), and percentage.

4. Compute: area, perimeter, circumference, diameter, radius, and volume for given problems.

5. Given a triangle and incomplete dimensions, use geometry to solve for the unknown angle and/or side.

6. Using the appropriate method, compute the dimensions of the largest square that can be cut from a given round piece of bar stock.

7. Using acceptable trigonometric methods, compute the angle of taper necessary to achieve specified dimensions for a tapered pin.

VERNIER SCALE AND DIAL MEASURING INSTRUMENTS

Upon completion of this module, trainee will be given an achievement test. Trainee will be considered successful if he can perform each objective listed below with the accuracy specified.

1. Given a drawing of an outside micrometer, determine the values represented by units on the barrel scale and the thimble scale. (100% accuracy.)

2. Given a drawing of an outside micrometer, take a total reading. (90% accuracy.)

3. Given a drawing of a vernier micrometer, determine the value that one unit on the vernier scale represents. (100% accuracy.)

4. Take a total reading from a vernier micrometer drawing. (90% accuracy.)

5. Given a drawing of a 25-division vernier caliper, determine the value represented by units on the main scale and the vernier scale. (100% accuracy.)

6. Take a reading from a 25-division vernier caliper drawing. (90% accuracy.)

7. Given a drawing of a 50-division vernier caliper, determine the values represented by units on the main scale and the vernier scale. (100% accuracy.)

8. Take a reading from a 50-division vernier caliper drawing. (90% accuracy.)

9. With a vernier caliper measure both inside and outside dimensions of sample objects to within .001". (90% accuracy.)

10. Given a drawing of a balanced type dial indicator, take the reading. Choose whether it is a high or low point reading. (100% accuracy.)

11. Given appropriate drawings, tell what the dial indicators are measuring (roundness, surface flatness). (100% accuracy.)

ENGINEERING DRAWINGS

1. Given engineering drawings of the complexity of the average shop drawing trainees will be able to do the following with 90% accuracy:

   A. Given the location of any part, identify, read the name or number and describe the part.

   B. Given part name, number or location, give its description and specifications, including:

      (a) Dimensions (length, width, diameter).

      (b) Physical Characteristics (finish, number and type of holes, pitch).

      (c) Type (bearings: ball or sleeve; threads: fine or coarse; holes: threaded or not, counter bored or spot faced, blind or through).

      (d) Tolerances

   C. Be able to define spatial relationships between given parts as follows: above or below, in, on or between, distance from one part to another.

2. Given a simple perspective drawing, sketch top and front view of the object with 100% accuracy.

LAYOUT WORK

Upon completion of this module, trainee will be given an achievement test and will be considered successful if he can perform each objective below with at least 90% accuracy:

1. Match the following geometric shapes with 100% accuracy with the drawing of each:

   A. Rectangle
   B. Square
   C. Diameter
   D. Radius
   E. Cube
   F. Right Angle
   G. Right Triangle
   H. Cone
   I. Parallel Lines
   J. Arc
   K. Circumference
   L. Tangent Line
   M. Perpendicular Lines
   N. Straight Angle
   O. Cylinder
   P. Equilateral Triangle

2. Indicate with 100% accuracy how many degrees are in:

   A. A straight angle
   B. Each of the angles in a rectangle

3. Given a drawing of a triangle identify the straight angle.

4. Given the diameter of a circle, compute the radius. (100% accuracy.)

5. Given the radius of a circle, compute the diameter. (100% accuracy.)

6. Indicate how many sides a cube has.

7. Using a combination square, scribe parallel lines on a flat piece of metal. Lines must be accurate to within 1/64".

8. Using the center head on a combination square, find the center point of a piece of round stock and mark it with a prick punch. Accuracy must be to within 1/32".

9. Using the protractor head on a combination square, scribe lines on a flat plate at specified angles. Accuracy must be to within 1°.

10. Using a combination square, scribe two perpendicular lines on a flat plate. Then, using the protractor head, scribe a line bisecting the angle. Accuracy must be to within 1/64".

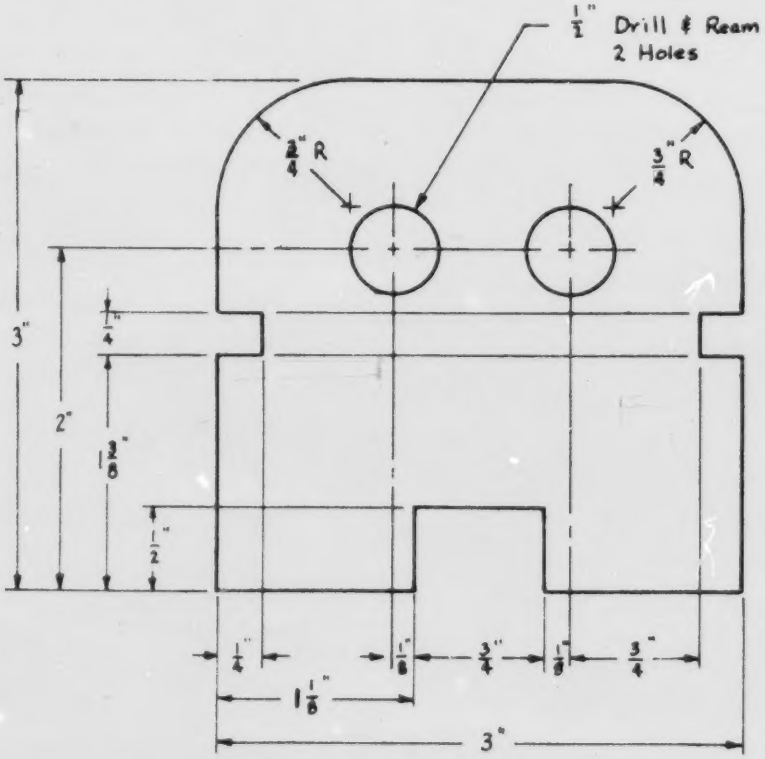
11. Using a rule and a hermaphrodite caliper, scribe the outline of a given rectangular groove. All dimensions must be accurate to within 1/64".

12. Scribe a square of a given dimension on a flat plate and scribe four circles within the square with accuracy such that the circles just touch each other and the edges of the square -- but do not overlap.

13. Given specific dimensions, scribe two concentric circles on a flat plate. Then scribe a circle of a given radius a specific distance from center of preceding two circles. All dimensions must be accurate to within 1/64".

14. Using a surface gage and appropriate holding devices, scribe lines which are parallel to the bottom edge of a flat plate. Accuracy must be to within 1/64".

15. On a flat metal plate, scribe a design equal in complexity to the one shown in the drawing below. All dimensions must be accurate to within 1/32".



BASICS OF METAL CUTTING

At the end of this unit, the trainee will be able to do the following with 90% accuracy:

1. State which material ferrous metals contain that are not found in nonferrous metals.
2. State whether ferrous and nonferrous metals react to magnets.
3. Distinguish between alloy and pure metals.
4. Define steel alloy.
5. Given a list of metals choose the nonalloy steel.
6. State the basic steel from which alloy steels are made.
7. Answer several problems related to the designation system for iron and steel.
8. Choose the effect carbon has on steel.
9. Given a specific piece of steel and a color chart, tell the color it will be coded, where it will be found and it's main alloy.
10. Given drawings of particular types of stress, state the strength required for high resistance to given stress.
11. Be able to match drawings to the following properties: brittleness, ductility, malleability and elasticity.
12. Describe what Rockwell and Brinell numbers refer to.
13. Given drawings of applications of hardness testers, identify the method used and the characteristic being tested.
14. Identify a definition of case hardening.
15. Identify a definition of annealing.
16. Choose the proper outcome of tempering a piece of hardened steel.
17. Give the rating of Bessemer screw stock (B1112).
18. Given metals and their machinability ratings, indicate which is easier to cut.

19. State what three materials most modern cutting tools are made of, and list them in order of hardness.

20. Name the type of cutting tool that is best for high speed machining.

21. List the two main jobs of cutting fluid.

22. Given pictures of correct and incorrect use of cutting fluid, select the one which is correct.

23. On drawings of metal being cut on a lathe, milling machine and drill, label arrows to show which motion constitutes speed and which motion constitutes feed on each.

24. Indicate what SFPM must be converted into to be useful. State the formula and apply it to given problems.

25. Give and apply formula for converting inches per revolution to inches per minute.

26. Given necessary data, calculate the proper speed in RPM and feed in inches per minute for milling and drilling.

27. Using a speed and feed calculator give speeds and feeds for rough and finish cutting on a given problem.

28. Given a chart of guidelines to determine depth of cuts for various types of machining, and cutting tools for a given problem, determine the total amount to be rough cut, the number of cuts and the depth of each.

WORKHOLDING DEVICES -- SLOTTED MACHINE TABLES & SURFACE GRINDERS

Upon completion of this module, trainee will be considered successful if he can perform each objective listed below with 90% accuracy.

1. Given a series of drawings, discriminate between correct and incorrect applications of blocks, clamps, T-bolts and other devices used to hold work on a slotted table.

2. Set up sample workpieces on a slotted machine table using appropriate holding devices (T-bolts, clamps, blocks, angle plates, C-clamps and planer jacks).

3. Set up work samples in a vise using parallel bars and hold downs.

4. Given drawings of flanged, swivel and universal vises, identify each.

5. Using a flanged or swivel vise and parallels, clamp a flat workpiece so that paper slips, placed at all four corners between the work and the parallels, are all held tight.

6. Mount and release a sample workpiece on a magnetic chuck.

7. Identify a production jig and briefly describe its use.

MILLING CUTTERS

1. Draw arrows on a picture to show the movements of the cutter and workpiece.

2. State safety precaution to be used when picking up cutters.

3. Identify from a drawing the spindle nose of a milling machine and state it's function.

4. Match pictures of cutters with straight, helical and staggered teeth with their respective advantages.

5. Given drawings of milling cutters, arbors and adapters, choose proper mounting device for each cutter.

6. Identify and label pictures of:

    a. End milling
    b. Side milling
    c. Straddle milling
    d. Face milling
    e. Plain milling (slab)

7. Given drawings, identify and label the cutters and match each with the type of milling for which it is best suited.

8. Label pictures of climb and conventional milling and match to a set of considerations (finish, power required, backlash, chatter, etc.).

LATHE HOLDING DEVICES

Upon completion of this module, trainee will be given an achievement test. Trainee will be considered successful if he can perform each objective below with the accuracy specified.

1. Given a drawing of an engine lathe, label the headstock, headstock spindle, tailstock, tailstock spindle and tool holder.

2. Name the rotating part of a lathe.

3. Draw arrows on drawings of facing and turning to show the direction of the movement of the workpiece and the cutting tool.

4. Given drawings of workpieces with circular machined surfaces, label them as to whether the surfaces are concentric or eccentric.

5. When a workpiece is fastened in a latne, it is checked to be certain it will be concentric when it rotates. Tell what the condition of <u>not</u> being exactly centered is called.

6. Given drawings of 3 and 4-jaw chucks, with chuck keys inserted in their slots, draw arrows to show the motion of the jaw or jaws when the key is turned in a given direction.

7. Given a drawing of a 3 or 4-jaw chuck, and a workpiece that appears too large to be held, explain how, or complete a simple sketch to show how, the jaws may be positioned to hold the piece.

8. Given a drawing of a long narrow workpiece mounted between centers, identify what piece is missing without which the workpiece will not turn.

9. Tell how spindle holes must be shaped in order to hold lathe centers.

10. Name the machining operation usually performed on a workpiece before it can be held between centers.

11. Identify need for high pressure oil in a set-up with a stationary tailstock center.

12. Given drawings of lathe dogs properly and improperly seated in the drive plate slot, identify the one that is binding and tell what effect this will have.

13. Tell whether a workpiece to be cut off on a lathe should be held between centers or in a chuck and why.

14. Given drawings and descriptions of several workpieces to be machined on a lathe, select the most appropriate holding method for each from drawings of a selection of chucks, centers, faceplates, etc.

15. Explain how tapered shank accessories are removed from (1) headstock spindle holes and (2) tailstock spindle holes.

LATHE CUTTING TOOLS

At the completion of this module the trainee should be able to hand grind engine lathe tool bits for the most common lathe operations; i.e., turning, facing, boring, parting and thread cutting and perform each of the following with 90% accuracy.

1. On a blueprint or working drawing, label various surfaces with the lathe operation that is required to produce each, such as: turning, parting, facing, threading.

2. On a sample blueprint or working drawing, circle the name of the material to be machined.

3. On a top view of a tool blank, draw the recommended shape of cutting tools for these operations: cutting 60° threads, L.H. & R.H. Rough turning, L.H. & R.H.. General turning, Round nosed turning, L.H. & R.H. facing, Cut-off.

4. List the effects of increasing or decreasing the cutting angle of a tool bit.

5. Label front and side top rake and front and side clearance on a drawing of a tool bit. List the effects of increasing and decreasing each.

6. List the effects of increasing or decreasing the radius of a round nose tool bit.

7. Given three machining situations, select whether cutting tool should be HSS, Steelite or Carbide.

8. Grind right and left hand turning tools with the proper clearance and rake angles with the aid of a chart and given specifications including the material to be machined and the operation to be performed.

9. Use a bevel protractor to measure the side clearance and side back rake angles on a lathe tool bit. Indicate whether the side back rake is positive, natural or negative.

10. Grind a tool bit for cutting 60° V-form threads.

11. Grind a cut-off tool to specifications given. Use a H.S.S. tool blank and check angles with a bevel protractor to be accurate within 5°.

12. Given a blueprint of a part to be made on an engine lathe, grind the required tool bits from HSS blanks.

The operations required should include, heavy rough turning, finish turning and facing. Clearance and rake angles shall be determined from a chart and checked with a bevel protractor. Angles shall be correct to within 5° and the shape of the bit shall be as recommended in this module. The finishing tools shall be honed to final sharpness with an oil stone.

TWIST DRILL

PART I

At the completion of this module, the trainee will be able to do the following with 90% accuracy:

1. Given drawings of a drill chuck and several drills, choose the correct drill to be held in the chuck.
2. Choose the chuck key from drawings of several machine tools.
3. Describe the function of a drift pin from a drawing of one.
4. State how a tapered shank drill is held in a drilling machine.
5. State three ways to check the size of a drill.
6. Given the decimal diameter of three holes, as shown on a blueprint, select the proper drill size for each from a drill/decimal chart. Diameters given require drills in the numbered, lettered and fractional series.
7. From several drawings, choose the one showing the correct way to measure a drill with a micrometer.
8. State whether or not drill points are cone shaped.
9. Given several drills, identify a core drill and explain its use.
10. Given drawings of three incorrect drill points identify what is wrong with each.
11. Choose which cutting effects will be produced by an incorrectly shaped drill point.
12. Indicate what caution must be exercised when using a chuck key.
13. Identify correct drill point and clearance angles for a general purpose drill.
14. Give two symptoms of a dull drill point that are observable while drilling a hole.

TWIST DRILL

PART II

1. Given a general purpose drill bit, trainee will be able to sharpen it on a bench or pedestal grinder to the following specifications. The drill point angle must be 118 degrees ± 5 degrees, with both lip angles equal. The point must be centered as determined by measurement of the lip angles. The clearance angle must be 8 to 12 degrees, determined by observation. The web must not be too thick nor the cutting edges burned. Trainees will be able to complete this task to this standard in no more than 10 minutes.

THREADS AND TAPS

Upon completion of this unit, the trainee will be able to pass a test covering the following with a score of 90% or better.

1. Pick out labeled drawings of Unified National and American National thread forms as being the thread forms used for nuts, bolts and machine screw threads, rather than other forms, such as: acme, square, knuckle and buttress.

2. Determine the pitch of a bolt with a machinist's rule and the pitch of both bolts and nuts with a screw pitch gauge.

3. Use a tap drill chart to determine the threads per inch when given a screw size and a bolt number.

4. Recognize screw threads drawn on a blueprint with either the standard or simplified symbols. Discriminate between threaded and unthreaded holes on the sample blueprint.

5. Using a blueprint and a tap drill chart, give tap size, drill size, pitch, thread form and class of fit for each threaded hole.

6. Recognize taper, plug and bottoming taps and match them to a description of their principal applications.

REAMERS, COUNTERBORES, COUNTERSINKS AND SPOTFACES

At the completion of this module the trainee will be able to do the following things with 90% accuracy:

1. Given blueprints with specifications and several holes, give the size and type of tools required and the operation(s) required.

2. Given blueprints and specifications, choose from diagrams the proper tools for each hole.

3. Label pictures of reamers, countersink, counterbore, pilot and arbor.

4. Give definitions for several blueprint abbreviations.

GRINDING WHEELS

Upon completion of this module, the trainee will be considered successful if he can perform each objective below with the accuracy or acceptability specified.

1. Indicate how much space there should be between the tool rest and the grinding wheel and why this is important. (100% accuracy.)

2. List at least four safety rules that should be observed in any grinding operation. (100% accuracy.)

3. Describe the general makeup of a grinding wheel (kind of abrasive, grain size, bond grade, structure) which will be effective in performing a given grinding job on a specified type of metal. (Judged acceptable by instructor.)

4. Given a standard chart for marking grinding wheels, select from pictures one that will be effective in performing a specified grinding job. (100% accuracy.)

5. Test an unmounted grinding wheel for cracks. (Judged acceptable by instructor.)

6. Mount a grinding wheel on a bench or pedestal grinder. (Judged acceptable by instructor.)

7. Indicate what two conditions will prevent a grinding wheel from cutting freely and how to correct them. (100% accuracy.)

8. True and dress a grinding wheel using a wheel dresser or an abrasive stick. (Judged acceptable by instructor.)

9. Adjust the tool rest for proper spacing. (Judged acceptable by instructor.)

APPENDIX C

BEHAVIORAL OBJECTIVES

SHOP INSTRUCTION

INTRODUCTION TO THE HORIZONTAL AND VERTICAL MILLING MACHINE

Upon completion of this four part introduction, observing safety rules, trainees will be able to do the following with 100% accuracy:

1. Identify and operate the principal parts of:

   - a knee and column horizontal milling machine,
   - a Universal milling machine,
   - a knee and column vertical milliong machine, and
   - a RAM type vertical milling machine.

2. Start, stop, reverse and change speeds of the spindle throughout its complete range.

3. Check all feed dials for movement each time the spindle is engaged.

4. Stop spindle and disengage feeds if necessary.

5. Choose the correct method for mounting any given cutter.

6. Clean the spindle so the cutter will run true.

7. Recognize when adapters are needed, choose and mount appropriate adapters.

8. Remove and replace the draw-in bolt.

9. Safely clean cutter and arbor, so no chips are visible and the cutter runs true when mounted.

10. Mount arbors and the following cutters so that they are solidly held on the spindle and will run true when taking a .010" cut, and will give a good finish without chatter:

    - end mills,
    - shell end mills,
    - face mill, and
    - arbor type cutter. (Tighten arbor nut, release taper, unscrew draw-in bar, and check the adjustment of the arbor support bearing.)

11. Safely remove cutters and arbors.

12. Align and clamp in place a flat vertical surface of a workpiece or work holding device (such as a vice jaw or angle plate) to the longitudinal axis of the machine table accurately within .001" over the length of the surface as indicated on a dial instrument.

13. Same as 12 with the surface perpendicular to the axis of the machine table (cross feed).

14. Indicate all directions in which the workpiece and cutter can be moved on all machines. If operating a RAM type machine, clamp and unclamp the head. Move it to several positions, up and down, and set to any given angle with 1/2°. Reset it to exactly zero.

15. (a) If operating a fixed bed machine, (RAM) position the quill in and out. Lock it in place. Also, position the spindle carrier up and down and lock it in place.

    (b) If operating a fixed bed machine, set table control dogs for table limits and fast feed. Operate the table smoothly through at least one complete cycle.

16. Smoothly operate the knee up and down by hand, power feed and rapid power traverse.

17. Set trip dogs.

18. Operate the knee clamping levers. Set the elevation micrometer dial to 000.

19. Raise the table a precise distance and return it to the starting point using proper procedures to eliminate error due to backlash.

20. Cross feed the saddle in and out by hand, under power feed and rapid traverse.

21. Properly use clamping levers.

22. If trip dogs are installed, set them accurately.

23. Using proper procedures to eliminate backlash errors, set the cross feed micrometer dial to 000 and hand feed the saddle into a precise distance, then, stop and return the table to its original position.

24. Feed the table in both directions, longitudinally, by hand, under power and by rapid traverse.

25. Clamp and unclamp the table feed.

26. Using procedures to eliminate backlash errors, set the table feed micrometer dial to zero and hand feed the table.

27. Set at least three different feed rates into the machine, covering the range available.

28. Power feed the table left or right at least 6" each of the settings to observe the difference in the rate of movement.

29. If installed, apply and release the backlash compensator and state when it is used.

30. If machine has a universal table, unlock the table swivel locks, set the table to an assigned angle within 1/2° and lock it in place. Reset it to 0°.

31. Using a dial indicator, align the table at 0° to within .001" over the length of its travel and lock it in place.

MILLING MACHINE OPERATION

Meet the following specifications on at least four separate workpieces using safe milling practices. Trainee will be able to:

A. Select a cutter appropriate for the job to be done and properly mount it so cutter will easily take a roughing cut and no chatter occurs.

B. Mount the workpiece solidly, safely and accurately in a vise or clamp it to the table so the workpiece does not move during the operation.

C. Calculate proper feeds and speeds and set them on the machine. If necessary, adjust the speed and/or feed until the tool cuts smoothly and produces a good finish.

D. Compute the depth of cut to take a minimum number of rough and finishing cuts, giving a completed workpiece within given tolerances and having a good clean finish.

E. Accurately deburr workpieces and cutters, so surface appears smooth.

F. Plan ahead. That is, recognize and/or decide with 100% accuracy:

- the type of material required for the workpiece
- the size of material to be used
- the tolerances required for the operation
- the workholding devices necessary
- the type and size cutter required
- whether or not cutting fluid is required
- the measuring instruments required
- the tools (such as wrenches) required
- and assemble the necessary materials before beginning the machining process.

G. Locate the cutter (or spot the cutter) to a flat surface of the work using an appropriate method and set the elevation micrometer dial correctly.

H. Take a "clean up" cut, leveling the surface to be machined.

I. Check set-up for rigidity, so chatter does not occur.

J. If chatter occurs, correct it so a smooth cut can be taken.

K. Measure properly (within .001") using the appropriate instruments.

L. Produce a finish that is smooth in appearance and to the touch.

M. Perform the following milling operations:

1. Plain (slab) mill any flat surface to within .005" of specified dimensions, or if milling to a layout line, split the layout line.

2. Side mill a slot (or keyway) to within .005" of given dimensions, on a flat surface, or split the layout line.

3. Form mill a radius to within .005" of specified dimensions.

4. Saw a slit to within .005" of specifications given, allowing for width of the cutter in crossfeeding the work.

5. Given a blueprint or shop sketch, face mill on a flat surface until it is smooth and even (as judged by the instructor or foreman).

6. End mill a slot on a flat surface to within 1/32" of given dimensions.

7. End mill a pocket on a flat surface to within .005" of specified dimensions.

LATHE ORIENTATION

At the completion of this unit, observing safety rules, trainees will be able to:

1. (a) Identify with 100% accuracy the principal parts and controls of an engine lathe.

   (b) Clean the lathe and accessories so that workpieces, tools and centers can solidly and safely be mounted, without chatter or wobble.

   (c) Clean the ways so that the carriage will move smoothly along them.

2. Unlock the tailstock with the clamp bolt nut.

3. Move the unlocked tailstock throughout its range on the bed.

4. Lock the tailstock tightly in place so it will not move.

5. Set at least three different distances on the tailstock spindle to an accuracy of 1/32".

6. Lock the tailstock spindle in place with the binding lever so the handwheel and spindle will not move.

7. Properly insert and remove centers, key chucks and tapered shank drills from the tailstock spindle. They must be mounted securely.

8. Move the carriage smoothly using the handwheel.

9. Lock the carriage in place so the handwheel will not move it.

10. Unlock the carriage.

11. Operate the cross slide smoothly by hand.

12. Set the cross slide micrometer dial to a zero reference and lock the setting. (Dial moves with cross slide only.)

13. Adjust the cross slide to eliminate backlash.

14. Lock the cross slide tight so the handwheel will not move it.

15. Unlock the cross slide.

16. Set and lock the compound rest to an angle of 0°, 29°, 45° and 90° with an accuracy of ± 1/2°.

17. Set the compound rest micrometer dial to a zero reference and lock the setting.

18. Adjust the compound rest properly to eliminate backlash.

19. Set the compound rest any given depth within .005".

20. Mount a toolpost, toolholder and cutting tool securely, so the tool will cut accurately without chatter.

21. Align the point of the cutting tool with the point of the tailstock center.

22. Smoothly feed the lathe tool manually using the longitudinal and cross feed handwheels.

23. Change speeds and feeds on the machine to any given setting.

24. Operate the spindle control lever to start and stop the spindle or to apply a brake to it.

25. Using the longitudinal and cross feed levers, smoothly feed the lathe tool under power, without chatter.

26. Operate the feed reverse lever to change directions smoothly.

27. Properly mount a center-drilled sample workpiece between centers so it will not move under pressure, and then mount down the setting.

28. Properly mount a 3-jaw chuck on the headstock spindle, so it will hold a workpiece straight and solid.

29. Properly mount and center a sample workpiece in a 3-jaw chuck so it is straight and will not move under pressure. Then remove the workpiece and the chuck from the spindle nose.

30. Properly mount a 4-jaw universal chuck on the headstock spindle, so it will hold a workpiece solidly.

31. Properly mount and center a sample workpiece in a 4-jaw chuck so it is straight and will not move under pressure. Remove the workpiece and the chuck from the spindle nose.

LATHE OPERATIONS

Trainees, given a blueprint or shop sketch, will be able to:

1. Plan ahead. That is, recognize and/or decide with 100% accuracy:

   - the type of material required for the workpiece
   - the size of material to be used
   - the tolerances required for the operation
   - the workholding devices necessary
   - the type and size cutter required
   - whether or not cutting fluid is required
   - the measuring instruments required
   - the tools (such as wrenches) required
   - and assemble the necessary materials before beginning the machining process.

2. Choose and mount the appropriate tool and tool holder so tool takes a .200" cut smoothly without chatter. Position it at the correct angle within .01°. When necessary, grind the proper tool with correct angles, back and side rakes. Regrind and/or touch-up the tool for finish cuts with a sharpening stone or on a grinder, so tool gives a good clean finish.

3. Safely and accurately clean the lathe.

4. Mount chucks, centers, and workpieces safely, accurately and securely, so work is accurate within given tolerance and chatter does not develop.

5. Calculate and set proper feeds and speeds for maximum cutting efficiency. When necessary adjust either feed or speed until the tool is cutting smoothly.

6. Correct chatter when it occurs.

7. Center the tool.

8. Take a clean up cut, to eliminate "run out".

9. Check rigidity of set up.

10. Calculate the depth of cuts to take the minimum number of roughing and finishing cuts.

11. Measure accurately within .051" with appropriate tools. Tear down a set up and clean the lathe and work area.

12. Properly apply cutting oil when necessary.

13. Choose appropriate drills, reamers and bores and properly mount them.

Given a blueprint or shop sketch on at least four pieces, be able to:

TASK 8

Face the end of a piece until it is smooth. (Cutting inside-out or outside-in.)

TASK 9

Turn a workpiece to a shoulder to a tolerance of .005" diameter, 1/8" (.125") length. Be able to give the amount a given depth of cut reduces a diameter.

TASK 10

Turn a taper using the compound rest to within .050" of a given end diameter and to within .5° of a given angle.

TASK 11

Cut a groove and then cut off a piece to within .0312 (1/32") of a given dimension.

TASK 12

Break or chamfer an outside sharp edge with the side of a tool to within 1/64" (.0156").

TASK 13

Face, accurately centerdrill, make a pilot hole and drill a hole to within 1/32" of diameter size and .125" (1/8") of depth.

TASK 14

Bore a hole to within .005" of given dimensions, properly mount and use a positive stop, or make reference marks.

Measure the depth of the hole accurately with a telescoping gauge. Chamfer the inside edge of a hole.

TASK 15

Ream a hole to within .002" of diameter size and 1/32 (.0312") of depth size.

TASK 16

Turn, file, and polish (with emry cloth) on a lathe to within .001" of a given diameter and .0312 of a given diameter and .0312" of a given length. The trainee will first centerdrill and mount a piece between centers.

TASK 17

Cut a groove to within .005" of given width and depth dimensions.

Knurl a given area to a good medium knurl. The quality of the knurl is judged by the instructor.

TASK 18

Turn a (long thin) taper using an attachment to within .005" of a given end diameter.

TASK 19

Cut screw threads to .005" accuracy.

ORIENTATION TO THE DRILLING MACHINES

DRILL OPERATION

Upon completion of this unit, observing safety rules, trainees will be able to:

1. Identify with 100% accuracy and properly operate the principle parts and controls of a precision drill press, a Radial drill press and a Universal drill.

2. Identify and operate the different types of drive including: variable speed drives (vari drive), step pulley system, and a gear drive system.

3. Correctly change spindle speeds on any type of machine from the slowest to the fastest speed, without damaging machine.

4. Smoothly operate the spindle hand and power feeds. Reverse spindle.

5. Set the depth stops accurately (within .001").

6. Safely and properly remove and mount chucks so that they will solidly hold a drill fit. Use a drill drift properly.

7. Accurately clean the machine so no wobble or run out occurs and hole drilled is straight.

8. Raise and lower the table. Clamp it in place so it will not move under pressure.

9. If a universal table, swivel it to several positions. Lock it in place. Unlock it and return it to its original position, relock it so it will not move under pressure.

10. Plan ahead. Choose and gather all necessary materials before drilling, so one does not have to leave the area during the operation.

11. Solidly, safely and accurately mount workpieces, so they will not move and the location of the hole drilled is accurate so that the vise is not damaged when the drill comes through the workpiece.

12. Calculate and set drill speeds and feeds for any given drill, so the drill will cut a clean hole without run out or chatter, giving a continuous chip.

13. Counterbore or countersink holes so that the appropriate screw will fit flush.

14. Accurately layout and centerpunch a workpiece to given dimensions, so hole location will be exact.

15. Choose the proper size drill, countersink, counterbore or tapping attachment and mount it properly, so operation can be completed without wobble or run out giving an accurate hole. Drill should run true.

16. Accurately deburr the workpiece, so that the piece appears smooth.

17. Hand feed the drill with correct amount of pressure, so a continuous non-blue chip comes out of each side of the hole.

18. If it occurs, correct wobble or "run out" until drill runs true.

19. Accurately position the head over the workpiece (Radial Drill), or position the work accurately under the drill, so the drilled hole is correctly positioned.

20. Properly apply cutting oil or, if so equipped, properly use coolant system, so drill will cut smoothly.

21. Accurately measure with the proper measuring device.

22. Tear down set-ups and clean up drill and surrounding area.

23. Regrind drills when necessary.

24. Drill pilot holes accurately.

TASK 20

Given a blueprint or shop sketch upon completion of Task 20, trainees will be able to:

1. Drill and countersink a blind flat head machine screw type hole to within .3125" of diameter dimensions given, and within 1/64" depth, so machine screw fits and will be flush.

2. Drill and counterbore a through socket head cap screw type hole to within .250", so screw will fit flush, $\pm$ 1/64".

TASK 21

Upon completion of Task 21, trainees will be able to:

1. Drill a large hole through and ream it to within .005" of given dimensions. Use several progressively larger drills for a very accurate, straight hole.

TASK 22

Upon completion of this task, trainee will be able to:

1. Accurately drill and tap a hole using the drill press. The hole should be clean, straight and true without damaging the tap (with or without a tapping attachment).

INTRODUCTION TO AND OPERATION OF THE SURFACE GRINDER

Upon completion, trainees will be able with acceptably safe performance to:

1. Identify with 100% accuracy and operate all principal parts and controls of a manually operated precision surface grinder and a surface grinder with hydraulic controls.

2. Choose, test, mount, true and dress the appropriate grinding wheel, so the wheel runs true, grinds a smooth even surface without breaking or chatter.

3. Properly set and adjust the table stops, so the end of the workpiece passes approximately 1" past the bottom of the wheel on each side.

4. Operate the table controls for crossfeed and reciprocating or traverse movement both manually and under power. Compute and set the crossfeed and table speed.

5. Mount both large and small workpieces securely, safely and accurately both on the magnetic chuck and with clamps or a vise, angle plates, bumper pieces. The piece should not move at all under operation.

6. Properly clean the grinder.

7. Produce fine finishes.

8. Accurately operate the grinding wheel downfeed, without damaging the wheel or workpiece.

9. Turn the magnetic chuck on and off for both permanent magnet and electromagnetic chucks. Identify its limitations.

10. Identify and use safety rules for grinding.

11. Plan ahead: choose and gather all materials necessary to complete a job before beginning the job.

12. Touch off.

13. Redress the wheel for finish cuts, so the wheel will produce a fine finish.

14. Calculate the depth of cut for a minimum number of rough and finish cuts, decreasing the depth with progressive cuts, and producing a fine finish within given tolerances.

15. Deburr workpiece, so it appears smooth (no jagged edges).

16. Break down the set-up, put tools away and clean the grinder and the surrounding area.

TASK 23

1. True and square all sides of a workpiece until they are smooth (no machining lines are present) and square, as judged by the instructor.

APPENDIX D

PRETESTS AND POST-TESTS
MILLING CUTTERS
METAL CUTTING FUNDAMENTALS

Name_____ Date_____

Company_____

Time Started _____

REVIEW EXERCISE

MILLING CUTTERS

F I E L D T E S T C O P Y

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Do as much of this exercise as you can. If you do not know how to work some of the questions, that's all right. You will learn how later. If you have trouble on a question, leave it and move on.

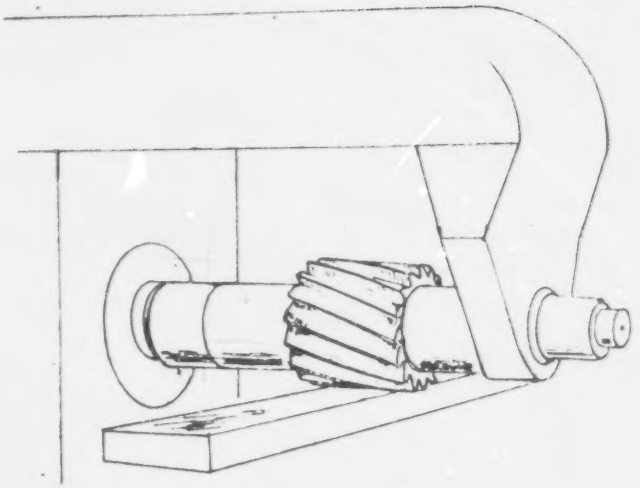
There is no pass or fail in this program. There is only SUCCESS! You will be guided through whatever teaching materials are necessary for you to become a fine, competent workman.

REVIEW/ACHIEVEMENT EXERCISE

MILLING CUTTERS

1. To select the correct milling cutter requires that you understand the milling process.

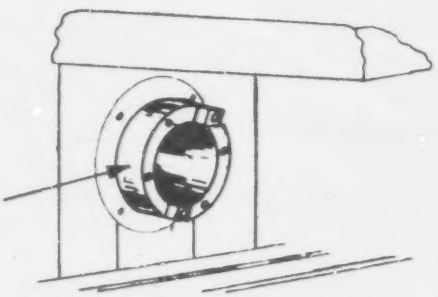
   Draw arrows on the drawing to show how the cutter moves and how the workpiece moves.



2. What safety precaution should be followed when picking up large, sharp milling cutters? _____

3. What is this part of a milling machine called? _____

   What is it for? _____

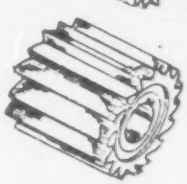


4. Some cutters have straight cut teeth. Others have helical (angled) teeth and some even have staggered teeth.

   Match the cutters below to the advantages given for the kind of teeth.

A

B

C 

   1. Cheap, easy to sharpen.

      _____

   2. Has plenty of room to clear the chips out of a deep cut.

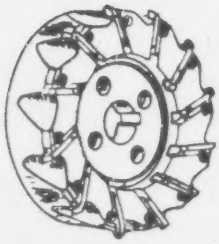
      _____

   3. Less chatter or vibration on wider cuts. _____

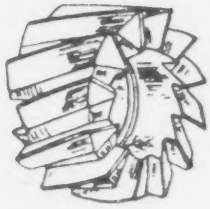
5. To mount the cutters shown below, which of the devices shown on the right would be needed?

MILLING CUTTERS

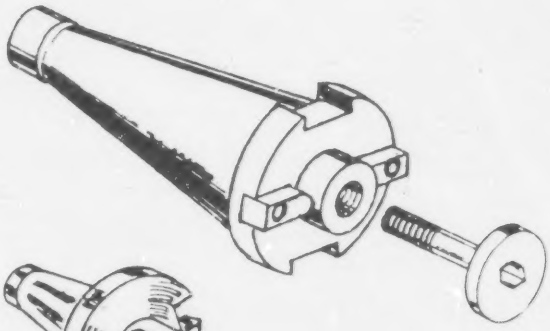
(1)

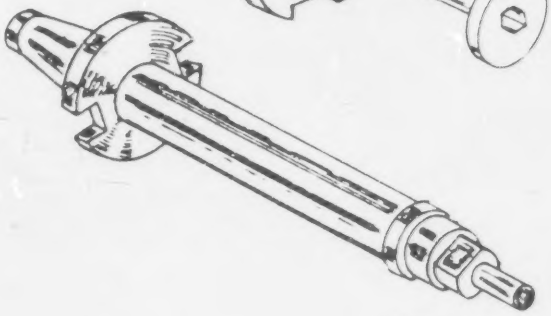
(2) 

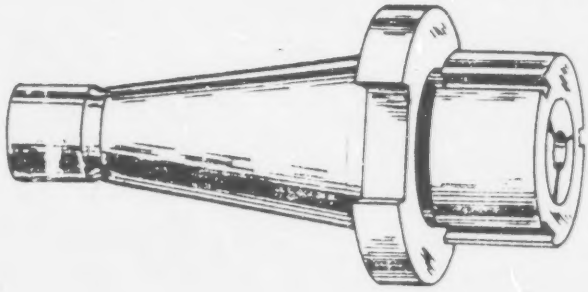
(3)

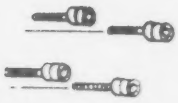
(4) 

ARBORS, ADAPTORS, ETC.

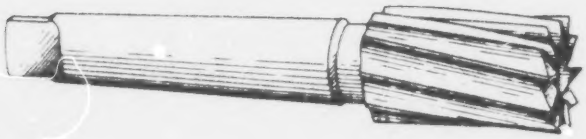
A 

B 

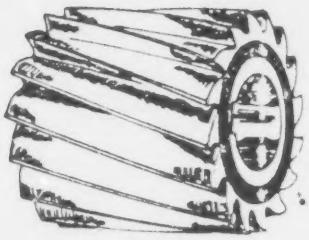
C 

D 

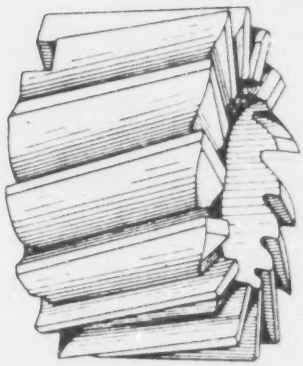
6. Tell if each of these cutters has left-hand teeth or right-hand teeth.



A _____



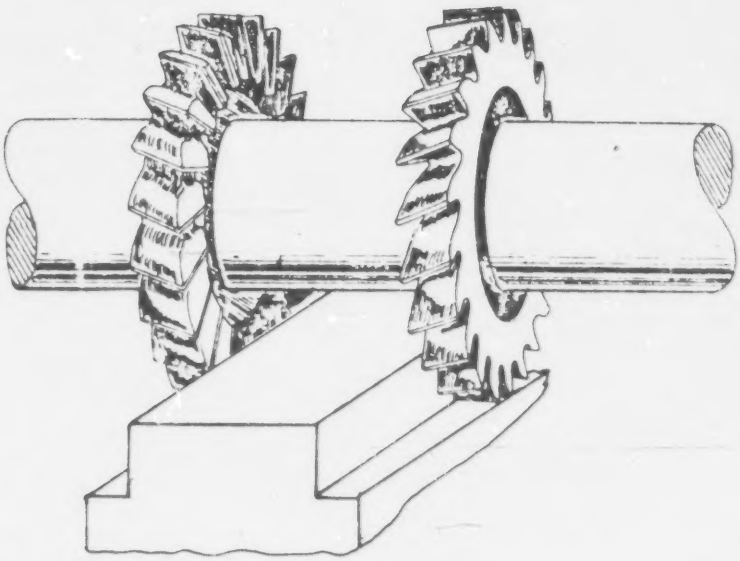
B _____



C _____

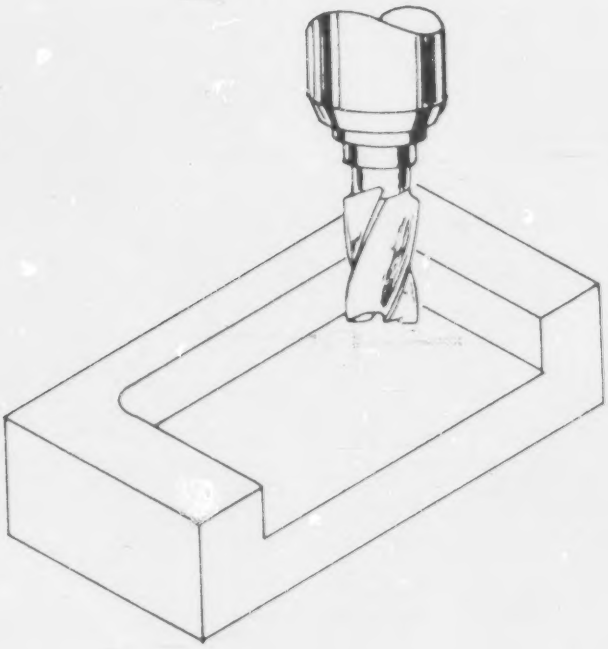
7. What is this kind of milling called?

_____



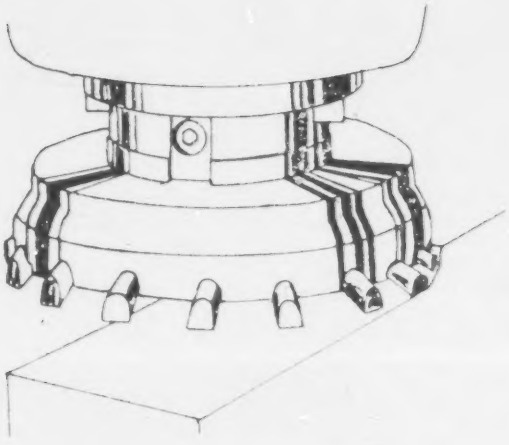
8. What kind of milling is this?

_____



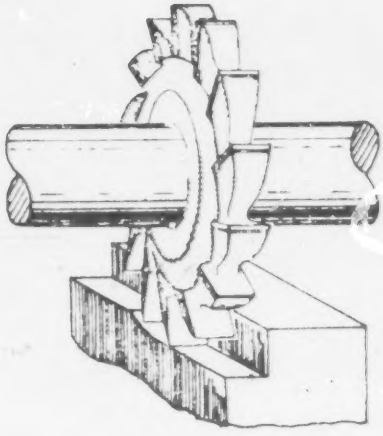
9. What is this kind of milling called?

_____

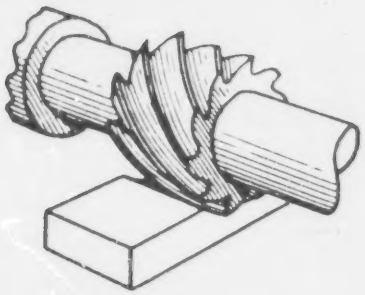


10. What is this kind of milling called?

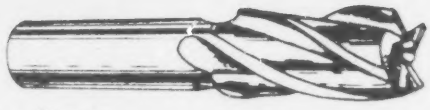
_____



11. What is this kind of milling called? _____

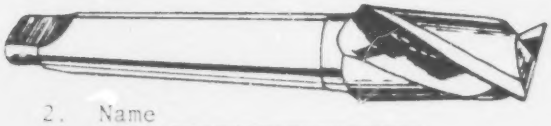


12. Beside each of these cutters, write its name and check which of the cuts shown at the right, it would be best for.



1. Name _____

Operation A B C

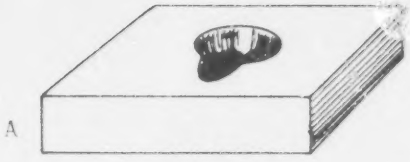


2. Name _____

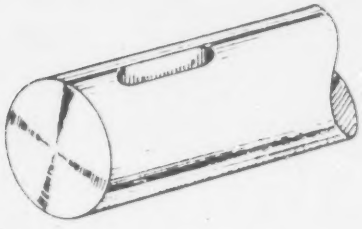
Operation A B C

3. Name _____

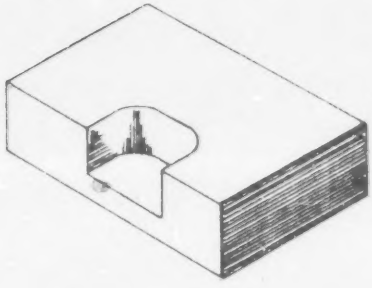
Operation A B C



A

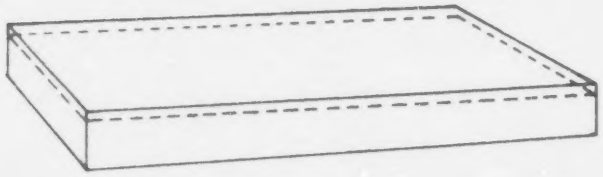


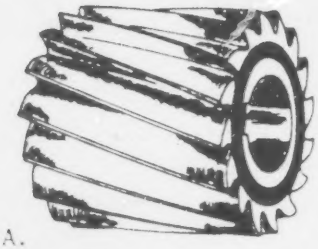
B



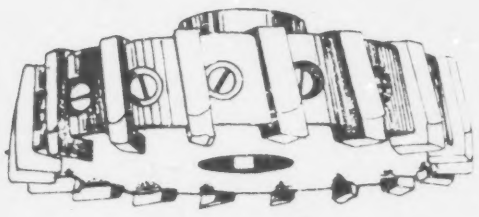
C

13. Which of these cutters could be used to mill the flat surface of this piece? (You may put more than one.) _____

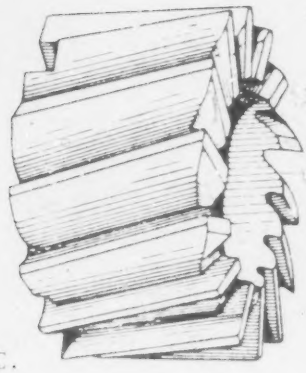




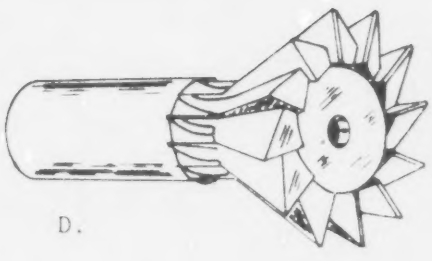
A.



B.



C.



D.

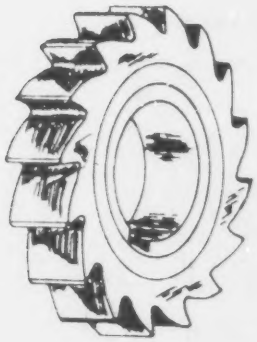
14. What are the names of the four cutters shown in No. 13 above? Choose from this list:

Ball End Mill	Staggered Tooth Side Cutter	Dovetail Cutter
Shell End Mill	T-Slot Cutter	Radius Cutter
2 Flute Reamer	Helical Plain Mill	Woodruff Key Cutter
Face Mill	2 Flute End Mill	Slitting Saw

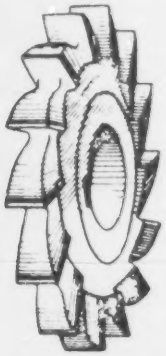
A _____ B. _____

C. _____ D. _____

15. These two cutters are used for different purposes. Name each cutter.

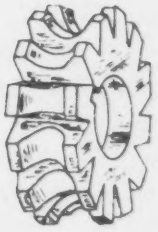


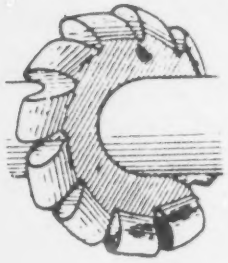
_____milling cutter



_____milling cutter

16. Cutters such as these, which cut shapes that are not <u>flat</u> surfaces are called?





Check One:

___A. Funny Cutters

___B. Form Cutters

___C. Shaped Cutters

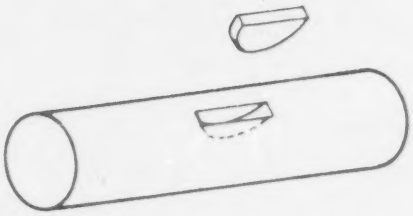
___D. Straddle Cutters

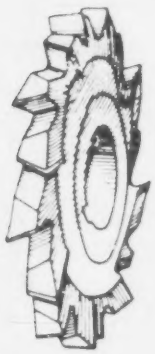
17. Which of the cutters below would be best to cut this keyway?

_____

Name the cutter.

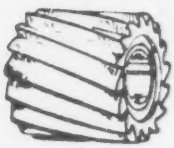
_____





A.

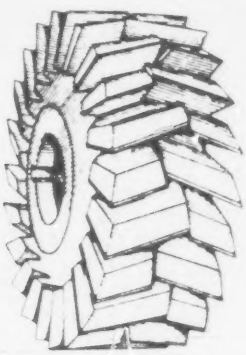
B.



C.

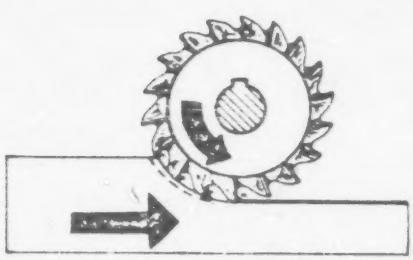
D.

18. One kind of milling cutter can have its width readjusted after it has been sharpened. It is called a _____.

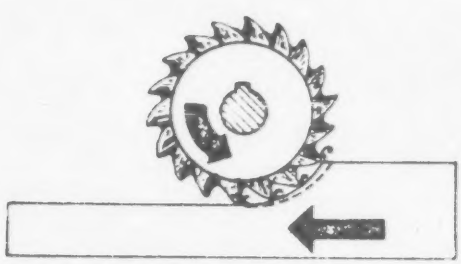


Adjustable Cutter
End Mill
T-Slot Cutter
Interlocking Cutter
Side Cutter
Slitting Saw
Shell End Mill
Dovetail Cutter

19. One of these pictures shows <u>climb</u> milling. The other shows <u>conventional</u> milling. Label them.



A. _____ milling



B. _____ milling

20. Both climb and conventional milling have certain advantages. Which of these statements apply?

conventional _____

climb _____

A. Requires a "backlash eliminator" on the milling machine.

B. Can be done on any milling machine.

C. Gives a better finish.

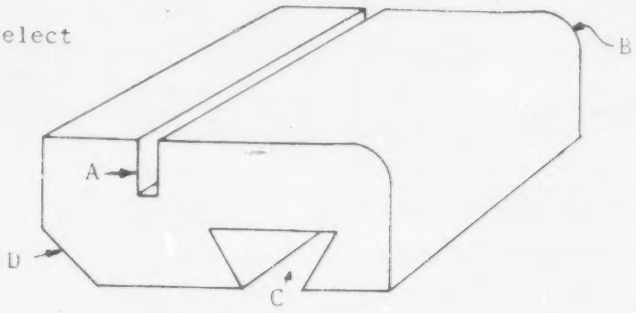
D. Used to get under hard surface scale.

E. Uses more power to feed the work.

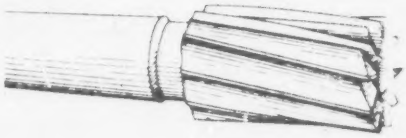
F. Cutters stay sharp longer.

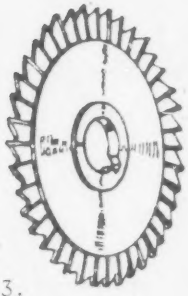
21. From the cutters shown below select the best one for cuts A, B, C and D.

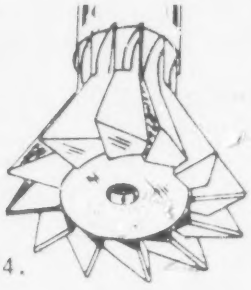
A. _____
B. _____
C. _____
D. _____



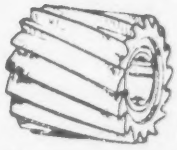
1.

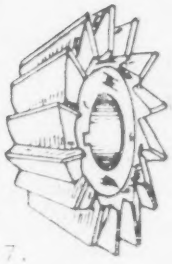
2. 

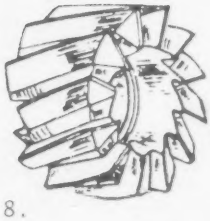
3. 

4. 

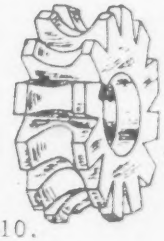
5.

6. 

7. 

8. 

9.

10. 

Time Completed _____

Name_____ Date_____

Company_____

Time Started: _____

REVIEW EXERCISE

METAL CUTTING FUNDAMENTALS

FIELD TEST COPY

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Do as much of this exercise as you can. If you do not know how to work some of the questions, that's all right. You will learn how later. If you have trouble on a question, leave it and move on.

There is no pass or fail in this program. There is only SUCCESS! You will be guided through whatever teaching materials are necessary for you to become a fine, competent workman.

1. What do ferrous metals contain that nonferrous metals do not? _____

2. Which type of metal reacts to a magnet?

___A. Ferrous

___B. Nonferrous

___C. Both of the above

3. Which metal does not belong?

___A. Copper

___B. Zinc

___C. Steel

___D. Tin

Why?

4. A steel is called an alloy when it:

___A. Contains a large portion of iron.

___B. Is a mixture of two or more metals.

___C. Contains no iron.

___D. None of the above.

5. Which kind of steel below is not an alloy steel?

___A. Chromium

___B. Carbon

___C. Nickel

___D. Molybdenum

. What is the basic steel from which alloy steels are made? _____

. What does the first digit in a code number show?
_____

SAE 4140

. What is the carbon content in 1045 steel? _____

. What effect does carbon have on steel?

___ A. It increases the hardness and strength.

___ B. It makes the steel softer.

___ C. It makes the steel lighter.

e table on the next page shows the color code for different kinds of steel. Suppose u're sent to the metal crib for a bar of 4150 steel 3" in diameter.

. What color will you look for? _____

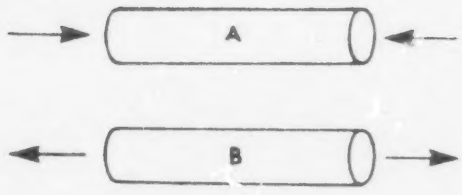
. Where is the color painted on the bar? _____

2. What is the main alloying metal used in the bar? _____

The table below shows the color code for different kinds of steel.

TYPE OF STEEL	SAE NUMBER	COLOR
Carbon	1010, 1015, X1015 1020, X1020 1025, X1025 1030, 1035 1040, X1040 1045, X1045 1050 1095	White Brown Red Blue Green Orange Bronze Aluminum
Free Cutting	1112, X1112 1120 X1314 X1315 X1335, X1340	Yellow Yellow & Brown Yellow & Blue Yellow & Red Yellow & Black
Manganese	T1330, T1335, T1340 T1345, T1350	Orange & Green Orange & Red
Molybdenum	4130 X4130 4135 4140, 4150 4340, 4345 4615, 4620 4640 4815, 4820	Green & White Green & Bronze Green & Yellow Green & Brown Green & Aluminum Green & Black Green & Pink Green & Purple
Chromium	5120 5140, 5150 52100	Black Black & White Black & Brown
Chromium-Vanadium	6115, 6120 6125 6130, 6135 6140 6145, 6150 6195	White & Brown White & Aluminum White & Yellow White & Bronze White & Orange White & Purple
Tungsten	71360 71660 7260	Bronze & Orange Brown & Bronze Brown & Aluminum
Silicon-Manganese	9255, 9260	Bronze & Aluminum

13. What kind of strength does a metal have when it has a high resistance to the type of stress shown in the drawing:



A?_____

B?_____

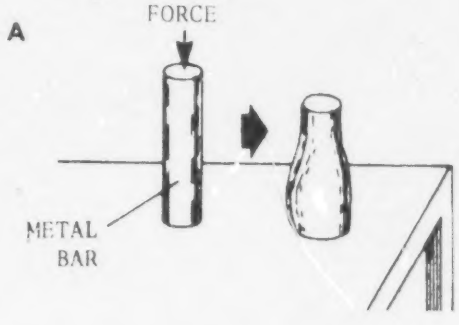
Match each characteristic at the left below with the proper drawing at the right.

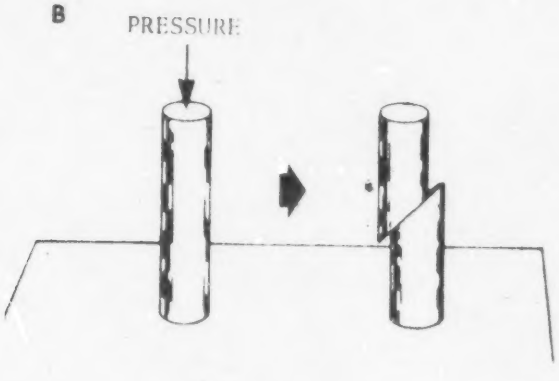
14. Brittleness_____

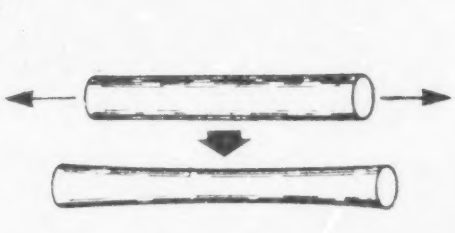
15. Ductility_____

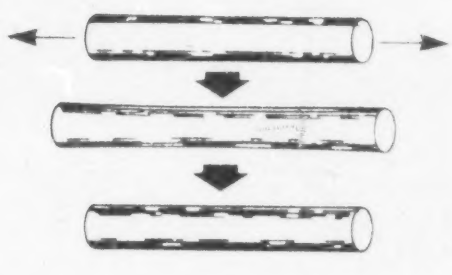
16. Malleability _____

17. Elasticity _____







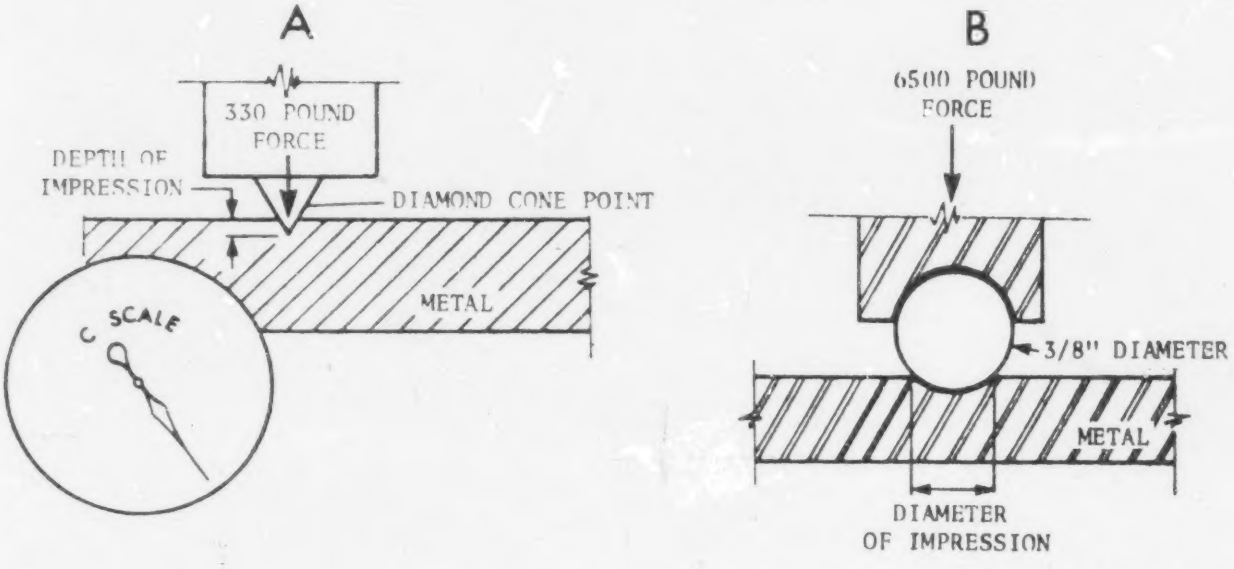


18. What do ROCKWELL and BRINELL numbers refer to?_____

35 Rc
Brn. 321

19. What characteristic is being tested in the drawings below?_____

What method is used in A?_____ In B?_____



20. Case hardening means that the metal has been:

___A. Softened to make it easier to machine.

___B. Annealed.

___C. Tempered.

___D. Hardened only on its surface.

21. What is the heat treating process called that reduces the hardness of the metal to make it easier to machine?

___A. Tempering.

___B. Annealing.

___C. Case Hardening.

___D. Quenching.

22. Tempering a piece of hardened steel makes it:

___A. Harder.

___B. Softer.

___C. Flexible.

___D. Less Brittle.

23. Bessemer screw stock (SAE 1112) is rated as having the best machinability. What is its rating? _____

24. Carbon steel (SAE 1020) has a machinability rating of 60 percent. Nickel chromium alloy steel (SAE 3115) has a machinability rating of 50 percent.

Which is easier to cut? _____

25. What three materials are most modern cutting tools made of? List them in order of hardness.

(1) _____

(2) _____

(3) _____

26. Which type of cutting tool material is best for high speed machining?

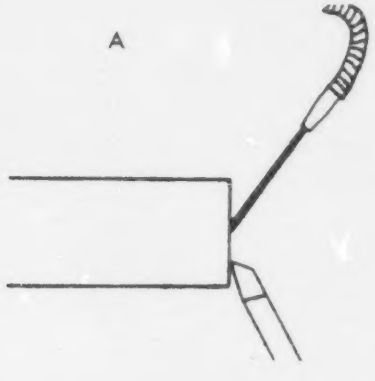
_____

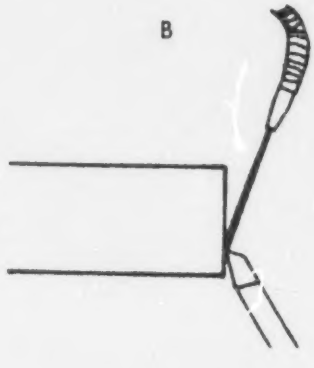
27. A cutting fluid has two main jobs. What are the

(1) _____

(2) _____

28. In which drawing is the cutting fluid being applied properly? A B
Why? _____

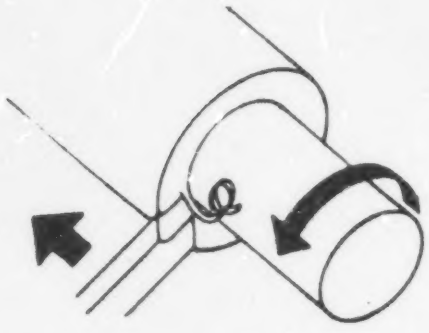




In each drawing below, label the proper arrows to show speed and feed motions.

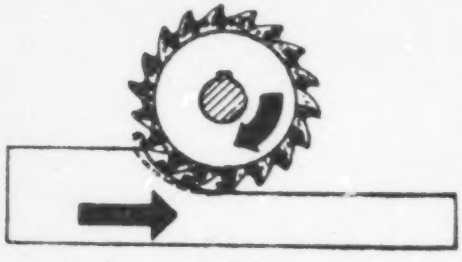
29.

LATHE

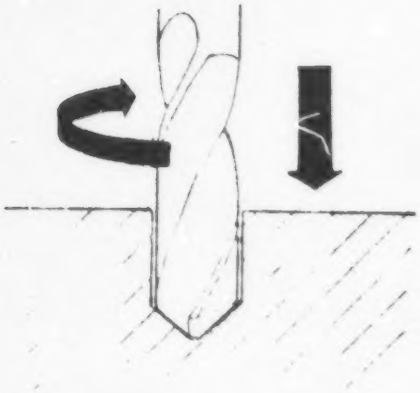


30.

MILLING MACHINE



31.



32. Cutting speeds are given in surface feet per minute (SFPM).

In order to set cutting speeds on a lathe or milling machine, you need to convert SFPM into _____.

33. Write the formula that can be used to make the conversion in question 32.

34. What spindle speed should you use to rough turn a piece of hard steel 3" in diameter on a lathe. The recommended cutting speed in SFPM is 30.

35. Figure the proper speed for a 5" diameter side cutter milling soft cast iron. The recommended cutting speed in SFPM is 90.

36. What spindle speed should you use to rough drill a $\frac{1}{4}$" hole in soft steel with a drill press. The recommended cutting speed is 60 SFPM.

37. Feed tables usually show rates in inches per revolution. But to find the feed setting to place in cutting machines, you need to convert inches per revolution to inches per minute.

Write the formula below.

38. A mill cutter with 4 teeth is turning at a speed of 100 RPM. The work is being fed at the rate of .005" per tooth.

What is the feed rate in inches per minute?

39. Determine the proper speed in RPM and feed in INCHES PER MINUTE for a 6" diameter side cutter with 16 teeth, milling bronze.

- The recommended cutting speed for bronze is 240 SFPM.
- The recommended feed per tooth is .013".

40. You need to drill a $\frac{1}{2}$" hole in a piece of soft steel.

- The recommended cutting speed for soft steel is 60 SFPM.
- The recommended feed rate is .005" per revolution.

Find the speed in RPM and the feed in INCHES PER MINUTE.

Use your speed and feed calculator to solve the next two problems.

41. Your job is to rough and finish mill a slot into a piece of hard cast iron with a $\frac{1}{4}$" diameter HSS end mill (2 cutting teeth).

Find the following:

(1) Starting speed for roughing in RPM _____

(2) Starting feed for roughing in IN/MIN _____

(3) Starting speed for finishing in RPM _____

(4) Starting feed for finishing in IN/MIN _____

42. Your job is to rough and finish turn a bar of 2" diameter hard steel to $1\frac{1}{2}$" diameter using a HSS tool bit.

Find the following:

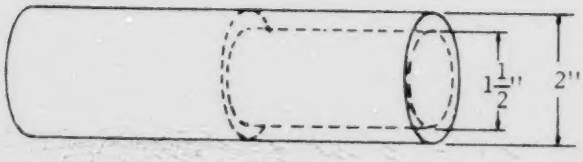
(1) Starting speed for roughing in RPM _____

(2) Starting feed for roughing in IN/REV _____

(3) Starting speed for finishing in RPM _____

(4) Starting feed for finishing in IN/REV _____

43. In Problem 42 you have to reduce the diameter of the bar by $\frac{1}{2}$" (.500").



Of this amount, let's suppose you decide to leave a finishing cut of .020".

Using the chart on the next page, determine the following:

(1) Total amount to be rough cut _____

(2) Number of roughing cuts you will need to make _____

(3) Depth of each rough cut _____

Time Completed _____

In the chart below are some guidelines to determine depth of cuts for various types of machining using HSS cutting tools.

TYPE OF MACHINING	*ROUGHING DEPTH OF CUT	**FINISHING DEPTH OF CUT
Face Milling	Up to .125"	.001"to .031"
Slab & Side Milling	.125	.001 to .031
Turning	.125	.0005 to .031
Boring	.094	.0005 to .016
End Milling		
$\frac{1"}{4}$ Dia. mill	.031	.001 to .016
$\frac{1"}{2}$	.063	.001 to .016
$\frac{3"}{4}$	.094	.001 to .016
1"	.125	.001 to .016
2"	.188	.001 to .016
Drilling	Roughing and finishing is determined by the rate of feed given under CUTTING FEEDS (inches per revolution) on the calculator.	

*ROUGHING DEPTH OF CUT -- The horsepower and condition of the machine, the condition of the cutting tool, the rigidity of the setup and the speed and feed being used will affect the depth of cut that can be taken. THE RATES ABOVE ARE ONLY GUIDELINES.

**FINISHING DEPTH OF CUT -- This is affected by the finish needed and the speed and feed being used. THE RATES ABOVE ARE ONLY GUIDELINES.

APPENDIX E

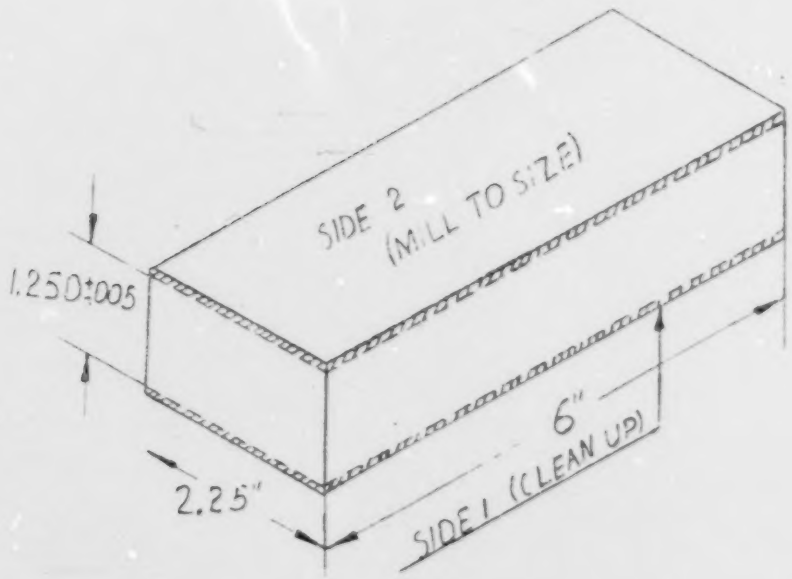
SAMPLES OF SHOP TRAINING ASSIGNMENTS SHEETS

TRAINING ASSIGNMENT SHEET

r Name _____ Company _____
k No. 1 Operation PLAIN (SLAB) MILLING

TRUCTIONS: SLAB MILL SIDE 1 TO CLEAN UP
SLAB MILL SIDE 2 TO SIZE

TERIAL: MILD STEEL BAR STOCK APPROX. 1.50"x2.25"x6"



l in the missing information in the Planning Section below and have your instructor
ck it before you begin.

ANNING SECTION: Trainee fill in all empty blanks.

rkpiece Material _____
chine _____
erances _____
rkholding Devices _____
ter: Material _____ Type _____
Diameter _____ Width _____
Number of Teeth _____
ting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough _____
Finish _____
Feed Rate: Rough _____
Finish _____
Approximate Depth of Cuts:
Rough _____
Finish _____
Measuring Instruments
Needed: _____
_____

STRUCTOR FILL OUT BELOW:

dent Time Required for Task ___ min. Instructor Time Required ___ min.

VELOPMENT SYSTEMS CORPORATION 500 NORTH DEARBORN STREET CHICAGO, ILLINOIS 60610

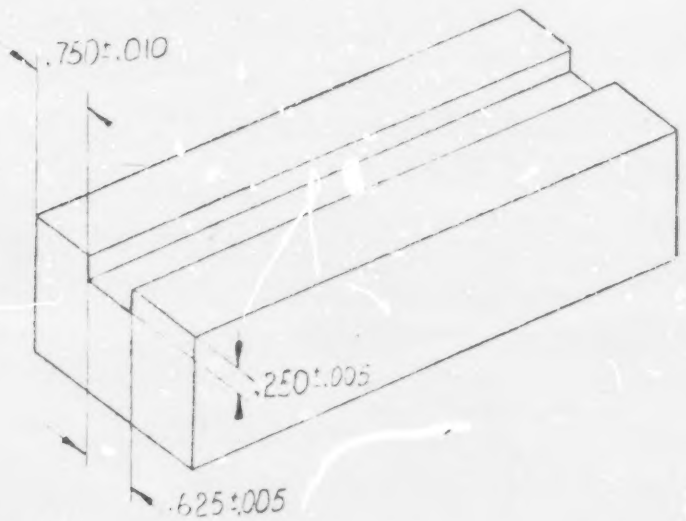
TRAINING ASSIGNMENT SHEET

Your Name_____ Company_____
Task No. 2 Operation Side Mill A Slot

INSTRUCTIONS:

Using the same sample workpiece as in Task 1, side mill a slot, as described below.

Fill in the missing information in the planning section below. Then have your instructor check it before you begin.



PLANNING SECTION: Trainee fill in all empty blanks.

Workpiece Material_____
Machine_____
Tolerances_____
Workholding Devices_____
Cutter: Material_____ Type_____
Diameter_____ Width_____
Number of Teeth_____
Cutting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough_____
Finish_____
Feed Rate: Rough_____
Finish_____
Approximate Depth of Cuts:
Rough_____
Finish_____
Measuring Instruments Needed:_____

INSTRUCTOR FILL OUT BELOW:

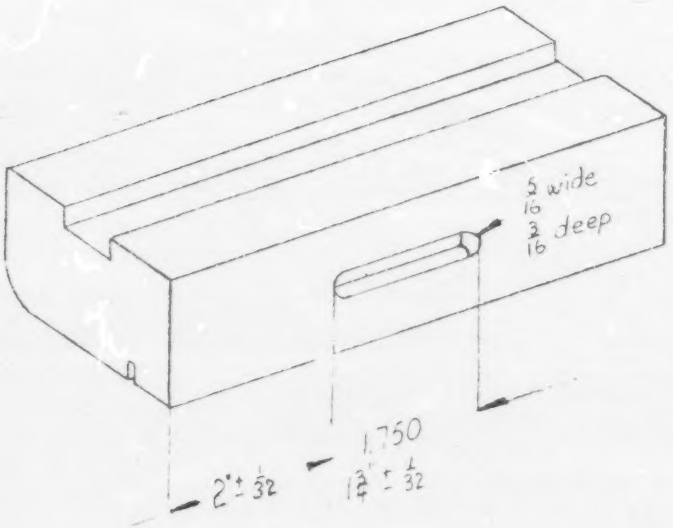
Trainee Time Required for Task___min. Instructor Time Required___min.

TRAINING ASSIGNMENT SHEET

our Name _____ Company _____
ask No. 5 Operation End Mill a Slot

NSTRUCTIONS:

ill in the missing information in the planning section below. Then have your instructor heck it before you begin.



LANNING SECTION: Trainee fill in all empty blanks.

orkpiece Material _____
achine _____
olerances _____
orkholding Devices _____
utter: Material _____ Type _____
Diameter _____ Width _____
Number of Teeth _____
utting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough _____
Finish _____
Feed Rate: Rough _____
Finish _____
Approximate Depth of Cuts:
Rough _____
Finish _____
Measuring Instruments Needed: _____

NSTRUCTOR FILL OUT BELOW:

rainee Time Required for Task ___ min. Instructor Time Required ___ min.

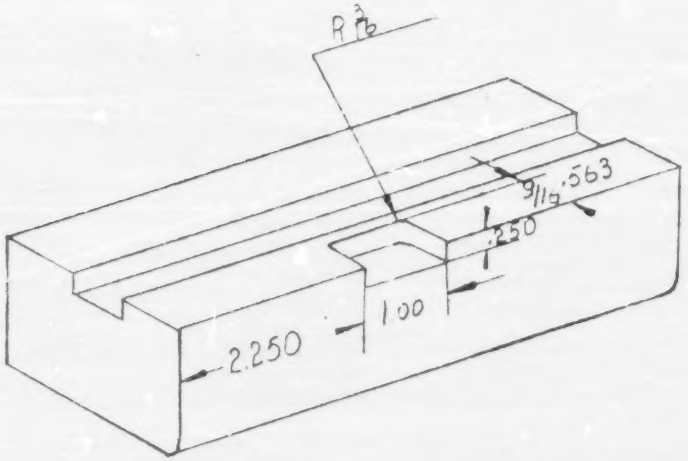
TRAINING ASSIGNMENT SHEET

our Name_____ Company_____
ask No. 7 Operation End Mill a Pocket

NSTRUCTIONS:

ill the pocket shown below. Use your project workpiece.

ill in the missing information in the planning section below. Then have your instructor heck it before you begin.



LANNING SECTION: Trainee fill in all empty blanks.

orkpiece Material_____
achine_____
olerances_____
orkholding Devices_____
utter: Material_____ Type_____
Diameter_____ Width_____
Number of Teeth_____
utting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough_____
Finish_____
Feed Rate: Rough_____
Finish_____
Approximate Depth of Cuts:
Rough_____
Finish_____
Measuring Instruments Needed:_____

NSTRUCTOR FILL OUT BELOW:

raining Time Required for Task___min. Instructor Time Required____min.

EVELOPMENT SYSTEMS CORPORATION 500 NORTH DEARBORN STREET CHICAGO, ILLINOIS 60610

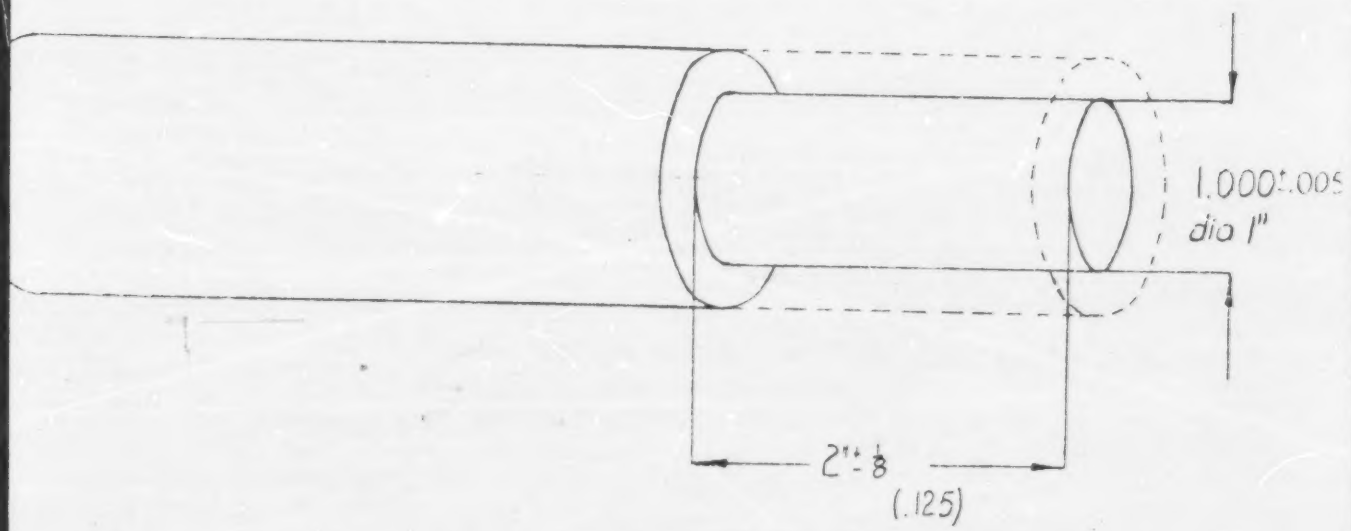
TRAINING ASSIGNMENT SHEET

ur Name_____ Company_____
sk No. 9 Operation Turn To Shoulder

STRUCTIONS:

ock: Same piece used in Task 8.

l in the missing information in the planning section below and have your instructor eck it before you begin.



NNING SECTION: Trainee fill in all empty blanks.

kpiece Material_____
hine_____
erances_____
kholding Devices_____
ter: Material_____ Type_____
Diameter_____ Width_____
Number of Teeth_____
ting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough_____
Finish_____
Feed Rate: Rough_____
Finish_____
Approximate Depth of Cuts:
Rough_____
Finish_____
Measuring Instruments Needed:_____

TRUCTOR FILL OUT BELOW:

inee Time Required for Task____min. Instructor Time Required____min.

LOPMENT SYSTEMS CORPORATION 500 NORTH DEARBORN STREET CHICAGO, ILLINOIS 60610

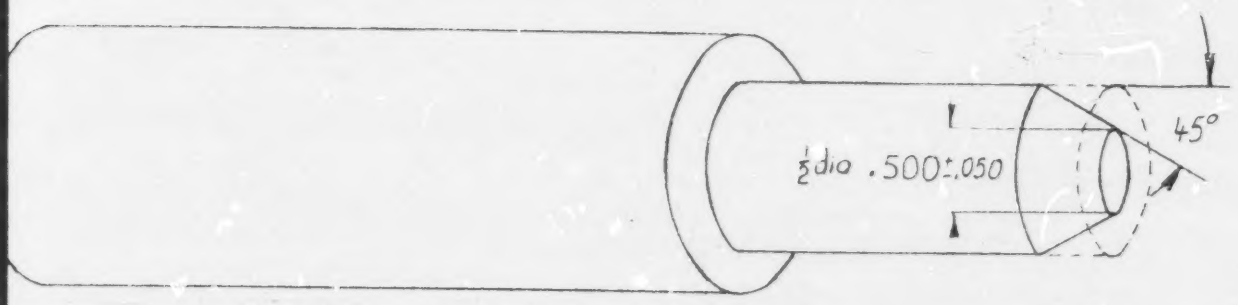
TRAINING ASSIGNMENT SHEET

ur Name_____ Company_____
sk No. 10 Operation Turn Taper with Compound

STRUCTIONS:

ock: Same piece used in Task 9.

ll in the missing information in the planning section below and have your instructor eck it before you begin.



ANNING SECTION: Trainee fill in all empty blanks.

rkpiece Material_____
chine_____
lerances_____
rkholding Devices_____
tter: Material_____ Type_____
Diameter_____ Width_____
Number of Teeth_____
tting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough_____
Finish_____
Feed Rate: Rough_____
Finish_____
Approximate Depth of Cuts:
Rough_____
Finish_____
Measuring Instruments Needed:_____

STRUCTOR FILL OUT BELOW:

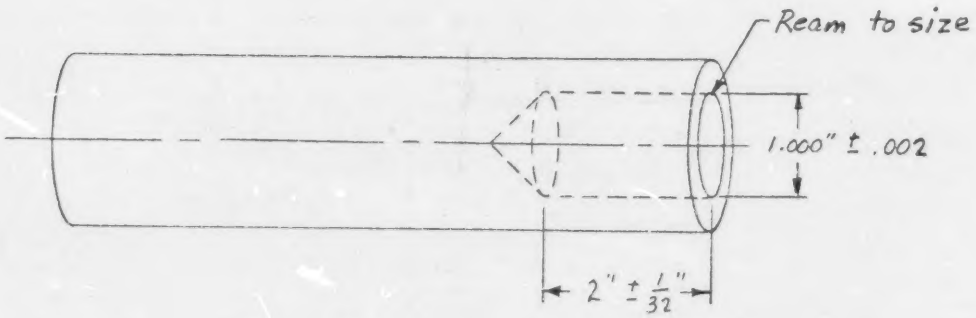
ainee Time Required for Task___min. Instructor Time Required____min.

TRAINING ASSIGNMENT SHEET

ur Name_____ Company_____

sk No. 15 Operation Ream hole to size

STRUCTIONS:



Cold Rolled bar stock used in Tasks 13 & 14

ANNING SECTION: Trainee fill in all empty blanks.

rkpiece Material_____
chine_____
lerances_____
rkholding Devices_____
tter: Material_____ Type_____
Diameter_____ Width_____
Number of Teeth_____
ting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough Not Required
Finish_____
Feed Rate: Rough Not Required
Finish Not Required
Approximate Depth of Cuts:
Rough Not Required
Finish Not Required
Measuring Instruments Needed:_____

STRUCTOR FILL OUT BELOW:

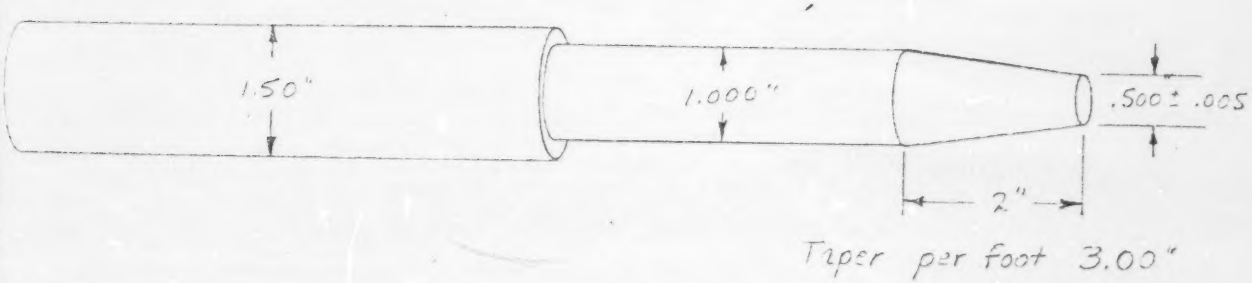
ainee Time Required for Task___ min. Instructor Time Required___ min.

VELOPMENT SYSTEMS CORPORATION 500 NORTH DEARBORN STREET CHICAGO, ILLINOIS 60610

TRAINING ASSIGNMENT SHEET

our Name _____ Company _____
ask No. 18 Operation Tapering

NSTRUCTIONS: (Same workpiece as Tasks 13 thru 17, or cold rolled bar stock)



Taper per foot 3.00"

ANNING SECTION: Trainee fill in all empty blanks.

rkpiece Material _____
chine _____
lerances _____
rkholding Devices _____
tter: Material _____ Type _____
Diameter _____ Width _____
Number of Teeth _____
tting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough _____
Finish _____
Feed Rate: Rough _____
Finish _____
Approximate Depth of Cuts:
Rough _____
Finish _____
Measuring Instruments Needed: _____

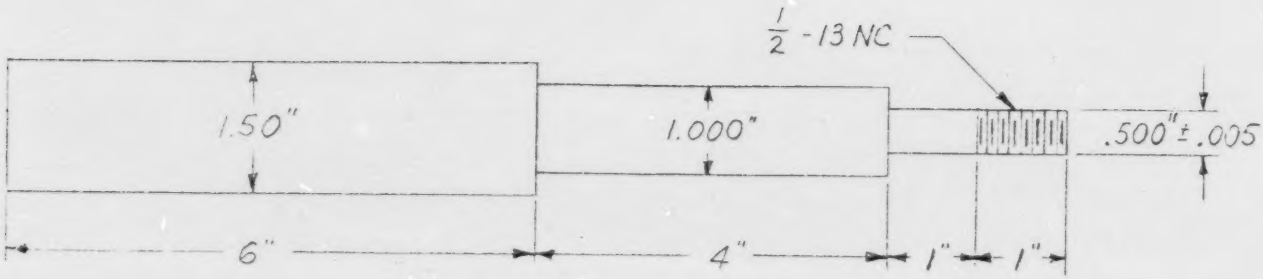
STRUCTOR FILL OUT BELOW:

inee Time Required for Task ___ min. Instructor Time Required ___ min.

TRAINING ASSIGNMENT SHEET

ur Name_____ Company_____
sk No. 19 Operation Screw Thread Cutting

STRUCTIONS: Piece from Task 18 or cold rolled bar stick.



ANNING SECTION: Trainee fill in all empty blanks.

rkpiece Material_____
chine_____
lerances_____
rkholding Devices_____
tter: Material_____ Type_____
Diameter_____ Width_____
Number of Teeth_____
tting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough_____
Finish_____
Feed Rate: Rough_____
Finish_____
Approximate Depth of Cuts:
Rough_____
Finish_____
Measuring Instruments Needed:_____

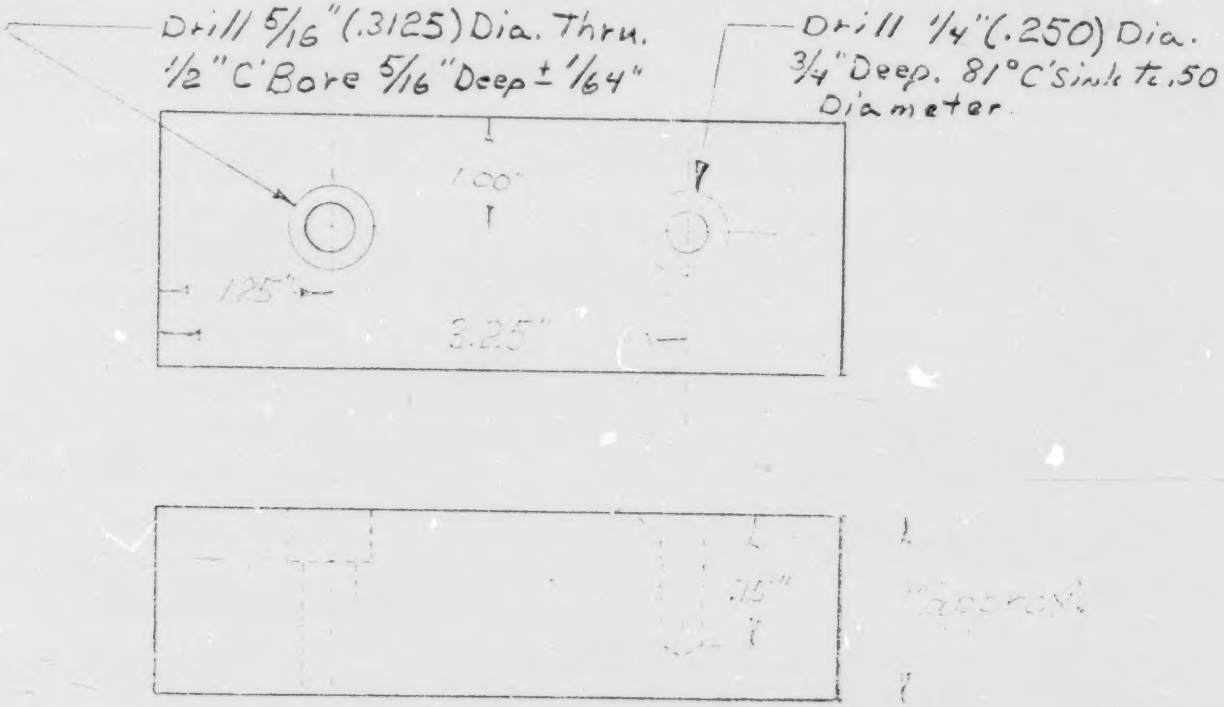
STRUCTOR FILL OUT BELOW:

ainee Time Required for Task____min. Instructor Time Required____min.

TRAINING ASSIGNMENT SHEET

ur Name _____ Company _____
sk No. 20 Operation Drilling, Countersinking, & Counterboring

STRUCTIONS:



Workpiece may be any rectangular block
mild steel, about 1" thick and at least 5" x 3"

ANNING SECTION: Trainee fill in all empty blanks, which pertain to this task.

rkpiece Material _____
chine _____
erances _____
rkholding Devices _____
ter: Material _____ Type _____
" Diameter _____ Width _____
Number of Teeth _____
tting Fluid: ☐Yes ☐No ☐Not Available

Spindle Speed: Rough _____
Finish _____
Feed Rate: Rough _____
Finish _____
Approximate Depth of Cuts:
Rough _____
Finish _____
Measuring Instruments
Needed: _____

STRUCTOR FILL OUT BELOW:

inee Time Required for Task ___ min. Instructor Time Required ___ min.

ELOPMENT SYSTEMS CORPORATION 500 NORTH DEARBORN STREET CHICAGO, ILLINOIS 60610

APPENDIX F

SHOP WORK ASSIGNMENT FORMS

SHOP WORK ASSIGNMENT BOOKLET

Company _____ Supervisor's Name _____

Type of Workpiece 1½ x 3 x 7 Workpiece Material 1020

Operations to be performed MILL SLOT Y LEDGE ON ONE END

	OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4
Type of Operation	MILLING	MILLING		
Work Holding Device	UNIVERSAL VISE	UNIVERSAL VISE		
Tolerances	T. 002" -.000	T. 002" -.000		
Type of Cutter or Tool	STAEGER TOOTH SIDE CUTTER	SIDE CUTTER		
Number of Cuts:				
Rough	9	9		
Finish	4	3		
Spindle Speed:				
Rough	56	32		
Finish	56	47		
Feed Rate:				
Rough	1⅛	1 7/16		
Finish	½	⅞		
Depth of Cut:				
Rough	.150"	1.50		
Finish	.020"	.020"		

DEVELOPMENT SYSTEMS CORPORATION
500 NORTH DEARBORN, CHICAGO, ILLINOIS 60610

TURN PAGE FOR EVALUATION SECTION

EVALUATION SECTION

Instructor Fill Out

	EXCELLENT			UNSATISFACTORY
Planning	4	3	2	1
Accuracy	4	3	2	1
Finish	4	3	2	1
Setup	4	3	2	1
Cutter Selection	4	3	2	1
Feeds & Speeds	4	3	2	1
Number of Cuts	4	3	2	1
Safety	4	3	2	1

Trainee Time Required _____ hours.

Instructor Time Required _____ hours.

Estimated time it would take a competent journeyman to complete this assignment 3 ~~minutes~~/hours.

Comments: _____

_____

_____

How long would it take an average apprentice who has completed his first year of training (2000 hours) to complete this job? (Assume he has had an average amount of training (for a 1st year apprentice) on the machine required.) _____ hours/minutes

SHOP WORK ASSIGNMENT FORM

Company _____ Trainee's Name _____

Type of Workpiece TWO PIECES 3/4 x 3 x 7 3/16 Workpiece Material MACHINE STEEL

Operations to be performed SQUARE END-Y MILL TO LENGTH, END MILL POCKET

	OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4
Type of Operation	SIDE MILLING	END MILLING		
Work Holding Device	VISE	VISE		
Tolerances	+.1 / -1/32	-.000 / +.002		
Type of Cutter or Tool	SIDE MILL	1/2 END MILL		
Number of Cuts: Rough	2	4		
Finish	2	3		
Spindle Speed: Rough	560	1500		
Finish	560	1500		
Feed Rate: Rough	1 1/8 IN/MIN	HAND		
Finish	1 1/8 IN/MIN	FEED		
Depth of Cut: Rough	.050	.050		
Finish	.026	.010		

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SHOP WORK ASSIGNMENT FORM

Company _____ Trainee's Name _____

Type of Workpiece 3 3/4 x 3 x 5 Workpiece Material TOOL STEEL H-21D

Operations to be performed BUP, MILL END & SIDE, FORM 45° ON SIDE, MILL SLOT, BORE HOLE, VERTICAL SHAPER
TWO SIZES

	OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4
Type of Operation	SLAB MILL TO SIZE	NOTCH OUT 2 SIDE 3/8" DEEP	SIDE MILL 45°	MILL SLOT
Work Holding Device	VISE	VISE	VISE	VISE
Tolerances	±.010"	+.000 -.002"	± 1/32"	+.000 -.010
Type of Cutter or Tool	HELICAL SLAB MILL	STAGGER TOOTH SIDE MILL	45° CUTTER	STAGGER TOOTH MILL
Number of Cuts: Rough	2	3	5	SEVERAL
Finish	1	1	1	
Spindle Speed: Rough	67	47	67	35
Finish		67		45
Feed Rate: Rough	7/8	1 1/2	1/2	1
Finish	11/16	3/8		3/4
Depth of Cut: Rough	.100	.100	.090	.125
Finish	.030	.020	.010	.020

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SHOP WORK ASSIGNMENT FORM

Company _____ Trainee's Name _____

Type of Workpiece RIVET HEADER Workpiece Material MILD STEEL

Operations to be performed MILL SLOT, FLATS ON BAR, MAKE FLANGE

	OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4
Type of Operation	MILL	MILL	MILL SLOT	
Work Holding Device	CLAMP TO TABLE	CLAMP TO TABLE	CLAMP TO TABLE	
Tolerances	± .001	± .002	± 1/64	
Type of Cutter or Tool	END MILL	END MILL	END MILL	
Number of Cuts:				
Rough	2	—	4	
Finish	1	1	1	
Spindle Speed:				
Rough	63	—	97	
Finish	97	122	122	
Feed Rate:				
Rough	2 1/8	—	2 3/4	
Finish	1	1 3/8	1	
Depth of Cut:				
Rough	.070	—	.115	
Finish	.010	.035	.040	

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SHOP WORK ASSIGNMENT FORM

Company _____ Trainee's Name _____

Type of Workpiece RIVET HEADER Workpiece Material 240 STEEL

Operations to be performed TURN, FACE, BORE

	OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4
Type of Operation	TURN	FACE	BORE	
Work Holding Device	CHUCK	CHUCK	CHUCK	
Tolerances	±.0005	± 1/64	±.0005	
Type of Cutter or Tool	3/8 HSS	3/8 HSS	1/4 HSS	
Number of Cuts:				
Rough	1	1	3	
Finish	1	1	1	
Spindle Speed:				
Rough	200	200	250	
Finish	250	250	300	
Feed Rate:				
Rough	.015	.015	.015	
Finish	.004	.004	.004	
Depth of Cut:				
Rough	.120	.040	.030	
Finish	.005	.005	.005	

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SHOP WORK ASSIGNMENT FORM

Company _____ Trainee's Name _____

Type of Workpiece ROUND BAR STOCK Workpiece Material STAINLESS STEEL

Operations to be performed _____

	OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4
Type of Operation	FACING	TURNING	GROOVING	TURN TAPER
Work Holding Device	3-JAW UNIVERSAL CHUCK	———	———	———
Tolerances	± 1/32	±.002	± 1/32"	± .010
Type of Cutter or Tool	RIGHT HAND ROUGHING TOOL	RIGHT HAND ROUGHING TOOL	CUT-OFF TOOL	RIGHT HAND TOOL BIT (ROUGHING)
Number of Cuts: Rough / Finish	1 / 1	4 / 2	4 / 1	5 / 5
Spindle Speed: Rough	369 RPM	288 RPM	181 RPM	228 RPM
Spindle Speed: Finish	457 RPM	369 RPM	181 RPM	228 RPM
Feed Rate: Rough	.0095	.0045 IPR	HAND	.0045 IPR
Feed Rate: Finish	.004	.0045 IPR	HAND	.0045 IPR
Depth of Cut: Rough	.050	.100	.030	.050
Depth of Cut: Finish	.020	.090, .012	.010	.002-.010

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Company _____ Trainee's Name _____

Type of Workpiece 2 PIECES 1 3/8 X 3 1/2" Workpiece Material HI 340 TOOL STEEL
TURN 1.250" DIA X 1.87" TO SIZE TURN 1.176" DIA X 3.1" X 1.000" X 1.00" .020" OVER SIZE

Operations to be performed UNDERCUT 1.1760"D, CHAMFER & CENTER DRILL BOTH ENDS, KNURL 1.250 DIA

	OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4
Type of Operation	TURNING 1.250 DIA	TURN 1.176" & 1.00 DIA	UNDERCUT	KNURLING
Work Holding Device	COLLET	COLLET	COLLET	COLLET / TAILSTOCK CENTER
Tolerances	±.010"	±.020"	—	—
Type of Cutter or Tool	RIGHT HAND LATHE TOOL	RIGHT HAND LATHE TOOL	UNDERCUT TOOL BIT	KNURLING TOOL
Number of Cuts:				
Rough	2	5	1	
Finish	1	1		
Spindle Speed:				
Rough	200 RPM	300 RPM	300 RPM	120
Finish	300 RPM	630 RPM		
Feed Rate:				
Rough	.005" PER REV	.005	HAND FEED	.010"
Finish	.003"	.0025		
Depth of Cut:				
Rough	.050"	.050"	.065"	
Finish	.025"	.020		

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SHOP WORK ASSIGNMENT FORM

Company _____ Trainee's Name _____

Type of Workpiece 1 3/8" X 3" Workpiece Material TOOL STEEL

Operations to be performed TURN 1.130 DIA, DRILL Y BORE .510 HOLE, TURN 10° TAPER, FORM .31" RADIUS BLEND IN TAPER TO 1.130 DIA Y .31 RADIUS, POLISH

	OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4
Type of Operation	DRILL Y BORE .510"	FORM .230" RELIEF UNDERCUT AT 45° CHAMFER	TURN TAPER 10° COLLET Y CENTER	FILE Y POLISH
Work Holding Device	COLLET	COLLET		COLLET
Tolerances	± .010"	± .010"		
Type of Cutter or Tool	15/64 3 7/64 31/64" DRILLS	BORING TOOL RH FIN. TOOL .030 UNDER RELIEF CUT CHAMFER	RH. FINISHING TOOL	SMOOTH FILE POLISHING PAPER
Number of Cuts: Rough	3	1 1 —	12	—
Finish	1	1 1 2	1	—
Spindle Speed: Rough	550 Y 300 R.P.M.	300 RPM 550 RPM —	300 RPM	—
Finish		150 550	550 R.P.M	700 RPM
Feed Rate: Rough	HAND	HAND	HAND	—
Finish	FEED	FEED	FEED	—
Depth of Cut: Rough	15/64" 1/8" 1/8"	.20" — —	.020"	—
Finish	1/64"	.010" — —	.010"	—

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SHOP WORK ASSIGNMENT FORM

Company _____ Trainee's Name _____

Type of Workpiece 1 1/2" DIA X 3" + 3/4" DIA X 6 1/2" Workpiece Material TOOL STEEL

Operations to be performed TURN 1 1/2" DIA, KNURL 1 1/2 DIA, TURN 1 1/8 DIA X 1/8 STEP, DRILL + REAM .687 HOLE .020" UNDERSIZE. TURN 3/4 DIA X 6 1/2 TO .702 DIA X 6.475"

	OPERATION 1	OPERATION 2	OPERATION 3	OPERATION 4
Type of Operation	1 1/2" TURNING	.687 HOLE DRILLING	REAMING	3/4" DIA TURNING
Work Holding Device	COLLET	COLLET	COLLET	COLLET + CENTER
Tolerances	± 1/16	—	+.000 -.017	+.020
Type of Cutter or Tool	R.H. FINISHING TOOL	3/16" 1/2" 21/32" DRILL	43/64 STRAIGHT FLUTED REAMER	R.H. FIN. TOOL
Number of Cuts: Rough	1	DRILL THRU	REAM THRU	1
Finish	1			1
Spindle Speed: Rough	300	600 + 300 R.P.M	—	600
Finish	600	—	300 R.P.M	600
Feed Rate: Rough	.007"	HAND FEED	HAND FEED	.007"
Finish	.0047"			.0047"
Depth of Cut: Rough	.030	5/16" 3/16 5/32"	1/64"	.030"
Finish	.010			.013"

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APPENDIX G

MACHINE TRAINING RATING FORM

MACHINE TRAINING RATING FORM

Please fill in or have apprentice complete all the information in the box below.

1. Apprentice's Name _____
2. Company _____
3. Number of hours on course _____ Trade _____
4. Please write on the lines below the approximate number of hours completed on each of the machines listed:

Horizontal Mill _____ hrs.		Vertical Mill _____ hrs.	
Engine Lathe _____ hrs.		Turret Lathe _____ hrs.	
Radial Drill _____ hrs.		Drill Press _____ hrs.	
Surface Grinder _____ hrs.			

TO THE SUPERVISOR: In the Training Assignment Booklet that accompanies this sheet, there are separate pages with sketches and specifications for 4 milling tasks, 7 lathe tasks, 3 drill tasks and one task on the surface grinder. Each task page also has a PLANNING SECTION with spaces where an apprentice or trainee would normally fill in information about the type of machine, work holding device, cutting tools, measuring instruments, tolerances and speeds and feeds he would use to complete each assignment.

1. Using the scales on the other side of this sheet, we would like you to rate the competence with which the apprentice or trainee described above is now capable of performing each of the tasks in the accompanying booklet. The numbers at the left correspond to the task numbers in the upper left corner of each page of the task booklet.

2. By circling the appropriate numbers, please provide two ratings for each task: RATING 1 is your estimate of the apprentice's ability to perform the machining operation required in each task; RATING 2 is your estimate of his ability to make all the judgements and decisions and complete all the information included in the Planning Section of each task page.

3. We would also like you to write, on the lines preceding each task number, (see reverse) your best estimate of how long it would take this first year apprentice to complete the Planning Section, to set up and to run each of the tasks. Record the times in hours - NOT MINUTES.

The scale numbers should be interpreted as follows:

5 - Excellent Performance--Is able to perform the task quickly, to tolerance and without help. High quality product. Is able to complete all planning information quickly and accurately.

4 - Above Average--Performs to tolerance but quality of finish may differ, or takes too much time, or may need some help or make some errors or omissions in either the task or the Planning Information.

3 - Below Average--May reach tolerances required but only after quite a bit of help and quite a few errors or omissions. Takes too long to complete Planning Section and to perform machine operation.

2 - Unsatisfactory--Takes far too long to complete task and Planning Section. May or may not reach tolerances but needs considerable help and makes too many errors or omissions.

1 - Does not know how to perform this task because he has not worked on this machine.

0 - Does not know how to complete the Planning Section Information. Has never been taught this information.

TASK NO.	RATING 1 Ability to Perform Machine Task	RATING 2 Ability to Complete Planning Section
3	5 4 3 2 1	5 4 3 2 0
4	5 4 3 2 1	5 4 3 2 0
6	5 4 3 2 1	5 4 3 2 0
7	5 4 3 2 1	5 4 3 2 0
9	5 4 3 2 1	5 4 3 2 0
10	5 4 3 2 1	5 4 3 2 0
13	5 4 3 2 1	5 4 3 2 0
14	5 4 3 2 1	5 4 3 2 0
15	5 4 3 2 1	5 4 3 2 0
17	5 4 3 2 1	5 4 3 2 0
19	5 4 3 2 1	5 4 3 2 0
20	5 4 3 2 1	5 4 3 2 0
21	5 4 3 2 1	5 4 3 2 0
22	5 4 3 2 1	5 4 3 2 0
24	5 4 3 2 1	5 4 3 2 0

APPENDIX H

TRAINEE QUESTIONNAIRE

EVALUATION QUESTIONNAIRE FOR ADMINISTRATORS

TRAINEE QUESTIONNAIRE

Recently you participated in or completed an experimental machinist training program. In that program, you used or are using separate programed self-instructional materials for your related instruction courses. For basic instruction on the mill, lathe, drill and grinder you used or are using audio/visual programs.

We would like your opinions about that training program. Please be as frank and honest as you can. Our purpose in asking these questions is to get your opinions on how we may improve the training program.

Please answer <u>every</u> question. Do not leave any questions blank.

1. Where did you complete the printed programed materials? (check one)

   ____ all in a classroom
   ____ part in a classroom, part in the shop
   ____ all in the shop
   ____ other (describe) _____

Now let's talk just about the <u>printed</u>, <u>programed materials</u> you used to complete the related instruction part of the course.

2. Compared to regular classroom instruction, how did you like using the programed materials? (check one)

   1. ____ I like them much better than regular classroom instruction.
   2. ____ I liked them a little better.
   3. ____ I liked them about the same as regular classroom instruction.
   4. ____ I liked them a little less.
   5. ____ I liked them much less.

   Why? _____

   _____

3. Compared to regular classroom instruction, how would you rate the learning effectiveness of the printed programed materials? (check one)

1. ____ They were much more effective as learning materials than regular classroom instruction.
2. ____ They were somewhat more effective.
3. ____ They were about the same as regular classroom instruction.
4. ____ They were somewhat less effective than regular classroom instruction.
5. ____ They were much less effective.

Why? _____

_____

4. How did you like the fact that you were able to move through the materials at your own pace? (check one)

1. ____ I like that aspect of the program very much.
2. ____ I liked it somewhat.
3. ____ I had no particular feeling about it.
4. ____ I disliked it somewhat.
5. ____ I disliked it very much.

Why? _____

_____

5. Compared to regular classroom instruction, did you feel you always had a better idea of how well you were doing as you went through the programed course? (check one)

1. ____ Yes, I had a much better idea than I would have in a regular course.
2. ____ About the same as a regular course.
3. ____ No, I didn't have as good an idea as I would have in a regular course.

6. How about the amount of help and attention you got from the instructor? (check one)

1. ____ I got as much help as I needed.
2. ____ I would have liked a bit more help and attention from the instructor.
3. ____ I would have liked a great deal more help.

7. Would you like to have other training courses like the self-pacing one you recently completed? (check one)

1. ____ Yes, I think it is a good way to learn.
2. ____ It doesn't matter to me one way or the other.
3. ____ No, I would prefer regular classroom courses where the instructor teaches you.

Now let's talk only about the audio/visual programs you used right at the machines.

8. Compared to the usual method of teaching machine operation - in which an instructor demonstrates to a group of students - how did you like the audio/visual method you used? (check one)

1. ____ I liked it much better than the regular method.
2. ____ I liked it a little better.
3. ____ I like one method as well as the other.
4. ____ I liked the A/V method a little less than the regular method.
5. ____ I liked the A/V method much less than the regular method.

9. How about the teaching effectiveness of the A/V method? (check one)

1. ____ It was much more effective than the regular demonstration method.
2. ____ It was a little more effective.
3. ____ It was about the same as the regular method.
4. ____ It was a little less effective.
5. ____ It was much less effective.

10. How about the amount of help and attention you got from the instructor? (check one)

1. ____ I got as much help as I needed.
2. ____ I would have liked a bit more help and attention from the instructor.
3. ____ I would have liked a great deal more help.

11. Would you like to have other training courses like the self-pacing one you recently completed? (check one)

1. ____ Yes, I think it is a good way to learn.
2. ____ It doesn't matter to me one way or the other.
3. ____ No, I would prefer regular classroom courses where the instructor teaches you.

12. Did you have particular difficulty with any part of the training program - either the printed or the A/V parts?

    Please tell us in your own words.

13. Please give us your suggestions on how the training program - both the printed and the A/V parts - could be improved.

Thank you for your help. We appreciate your efforts in helping us make this program as effective as possible.

EVALUATION QUESTIONNAIRE

We need your help in completing our evaluation of the experimental apprentice training program that was field tested recently in your organization.

Your frank and confidential answers to the following questions will help us to determine the strengths and weaknesses of the experimental program and to revise it so it is maximally useful and efficient.

Please answer every question to the best of your ability.

1. In your own words briefly compare the efficiency and effectiveness of the experimental program with more conventional first year apprentice training programs on each of the following points:

   A. The extent to which the printed programed material covered the related instruction subject matter essential for trainees to be able to perform their first year tasks on the shop floor.

   B. The learning effectiveness of the programed, related instructional materials compared to conventional classroom instruction.

C. The trainee time required to complete both related instruction and the A/V shop instruction using the self-pacing materials compared to conventional apprentice instruction.

D. The instructor time required by the experimental program (both related instruction and A/V shop instruction) versus that required by conventional training programs.

E. The effectiveness of the A/V shop instruction programs compared to the traditional instructor demonstration or one-on-one training on machine tools.

F. The comparative value of the self-paced approach compared to traditional group pacing instructional methods in apprentice training.

2. What do you feel are the major advantages and disadvantages of the experimental, individualized program compared to the more traditional approach?

Advantages:

Disadvantages:

3. Based on the results of this experimental program, do you believe it should be possible to accelerate apprentice training through the use of such individualized instructional techniques?

4. Please make additional comments on what you see as the implications of this type of program for apprentice training or for other types of technical training.

5. Please comment on whether you think such a self-paced program would be an effective way of helping a greater number of educationally disadvantaged youth to get into and successfully complete apprenticeship or skilled trades training programs.

6. Please comment on the extent to which trainees, when they completed the experimental program, were better or less well prepared to perform on the shop floor than trainees who have been in a conventional training program for a comparable period of time.

7. Make any additional comments you would like to make.

8. Please indicate your job by checking the appropriate title below.

____ Training Manager or Administrator

____ Instructor

____ Foreman

____ Journeyman, which trade? _____

____ Union representative

____ Other (specify) _____

Thank you for your help in this important research program.